Chapter 1: Measurement by Observation: The Classical and Representational Theories of Measurement.

1.1 Aristotle
The ancient Greek philosopher Aristotle (384-322 B.C) argued that the observable universe possessed quantitative and non-quantitative components:

Expressions which are in no way composite signify substance, quantity, quality, relation, place, time, position, state, action, or affection. To sketch my meaning roughly, examples of substance are ‘man’, ‘the horse’, of quantity such terms as ‘two cubits long’ or ‘three cubits long’, of quality, such attributes as ‘white’, ‘grammatical’ Logic (Organon) - Categories (iv, 4, 2", 25-5).

The importance Aristotle ascribed to the concepts of quality and quantity is evidenced by his devotion of the majority of the Categories section of Logic (Organon) to their discussion. His explicit definition of quality, however, is to be found in his Metaphysics (v, 14, 1020b, 1-2):

‘Quality’ means the differentia of the essence, e.g. man is an animal of a certain quality because he is two-footed, and the horse is so because it is four-footed; and a circle is a figure of particular quality because it is without angles - which shows that the essential differentia is a quality. - This, then, is one meaning of quality - the differentia of essence...

Quality exists as an independent category by the nature of how the essences of substance are differentiated:

Whereas none of the characteristics I have mentioned are peculiar to quality, the fact that likeness and unlikeness can be predicated with reference to quality only, gives to that category its distinctive feature. One thing is like another only with reference to that in virtue of which it is such and such; thus this forms the peculiar mark of quality Categories (8.11",15-20).

If qualitative, objects or their inherent properties are only comparable in themselves. This concept Aristotle took to human behaviour and was one of the first to advance a qualitative psychology. Habits, dispositions, health, sanity, mood and inborn abilities were his qualitative behaviours. The qualities of objects Aristotle termed “affective” as their perception is contingent on our sensory apparatus. Such affective qualities were colour, figure (straightness / curviness), hardness / softness and sweetness / sourness / bitterness. Importantly, he argued that qualities have contraries and that given two contraries, if one is a quality, so will be the other. If arrogance is a quality of human psychology then humility will also be qualitative.

Yet a quality cannot exist in something as a contrary. For example, an object which is white cannot exist simultaneously as an object which is black. Qualities with no logical
contraries exist; such as the colours red, white and blue, hence such qualities can vary by
degree in reference to themselves only. This variation is determined by the binary
relations of transitivity, antisymmetry and strong connexity. For example, there are two
dollops of red paint $A$ and $B$. $B$ is then mixed with white paint to become $B_i$. Thus $A$ is
redder than $B_i$ and $B_i$ is less red than $B$ was. There is no reference to any particular
amount of redness held by the two paint dollops.

Whilst arguing for the reality and truth of qualities, Aristotle knew that there were
natural phenomena that could be described as existing in some amount and their
properties could be compared with something other than themselves. These belonged to
his category of quantity:

'Quantum' means that which is divisible into two or more constituent parts of which each is
by nature a 'one' and a 'this'. A quantum is a plurality if it is numerable, a magnitude if it
measurable. 'Plurality' means that which is divisible potentially into non-continuous parts;
'magnitude' that which is divisible into continuous parts; of magnitude, that which is
continuous in one dimension is length... (Metaphysics, V, 13, 1020a, 7-13).

The peculiar mark of quantity was that quantitative objects are compared in terms of
equality and inequality:

...The most distinctive mark of quantity is that equality and inequality are predicated out of
it....That which is not a quantity can by no means, it would seem, be termed equal or
unequal to anything else. One particular disposition or one particular quality, such as
whiteness, is by no means compared with another in terms of equality and inequality but
rather in terms of similarity. Thus it is the distinctive mark of quantity that it can be called
equal and unequal (Categories, 6, 6\textsuperscript{b}, 30-35).

Quantities admit no variation of degree between them in themselves and each quantity
cannot be of two magnitudes. For example, if a boat is 3 cubits long it can only be this
length and no other, such as 5 cubits. This means that the relative terms 'great' and
'small' cannot in themselves describe comparison judgments between two quantities of
differing magnitude. Aristotle reasoned that for such judgments reference must be made
to an "external standard" (Categories, 6, 5\textsuperscript{b}, 20-25), for if there is not, "a mountain would
be never called small or a grain large.... for it happens at times that the same thing is both
great and small "(6, 5\textsuperscript{b}, 35-5). Although Aristotle did not explicitly state it as such, the
comparison of a quantity with an external standard pertinent to that particular quantity is
measurement.

Quantities also consist of parts which may or may not stand in relative position to
each other. For lines, planes and solids this argument holds but does not for quantities
such as time or the real number system whose parts could not be said to occupy a position. Aristotle realised the ambiguity of this argument and corrected himself later by saying: “It would be better to say that such parts had a relative order, in virtue of one being prior to another”. Here he realised something of great importance - quantities possess order; a property he also observed in the natural numbers. “Similarly with number: in counting, ‘one’ is prior to ‘two’, and ‘two’ is prior to ‘three’ and thus the parts of a number may be said to possess a relative order, though it would be impossible to discover any distinct position for each” (6, 5a, 30-35).

Aristotle further divided the quantity category into two - discrete and continuous. He argued those quantities which do not share a common boundary are discrete quantities. Discrete quantities are aggregates of certain objects, events and properties. The number of marbles in a bag, the number of birds in a tree and the number of correct answers in a test are all examples of such quantities. The numerical relations between the entities of these classes of discrete quantities can be discovered through the simple task of counting.

It was in discrete quantity that Aristotle firmly located his theory of number. For the ancient Greeks, the only numbers which existed were the positive whole numbers or natural numbers. Aristotle argued:

In the case of parts of a number, there is no common boundary at which they join. For example, two fives make ten, but the two fives have no common boundary, but are separate; the parts three and seven also do not join at any boundary. Nor, to generalise, would it ever be possible in the case of number that there should be a common boundary among the parts; they are always separate. Number, therefore, is a discrete quantity. (Categories, 6, 4, 15-30).

All discrete quantities, including speech, are multitudes composed of indivisible, individual units. As number is a discrete quantity, so are numbers indivisible and hence only whole numbers can exist (Rusnock & Thagard, 1995). Interestingly, Aristotle thought that 1 was not a number, merely the starting point for the counting of an aggregate of a particular kind. Number could be applied only to aggregates of a certain kind, as he argued:

....the one is not in itself the substance of anything. And this is reasonable; for ‘the one’ means the measure of some plurality, and ‘number’ means a measured plurality and a

---

1 Aristotle may have been intimidated by his old teacher Plato in this respect; as the latter argued: “... that arithmetic has a very great and elevating effect, compelling the soul to reason about abstract number, and rebelling against the introduction of visible or tangible objects into the argument. You know how steadily the masters of the art repel and ridicule anyone who attempts to divide absolute unity when he is calculating, and if you divide, they multiply, taking care that one shall continue one and not become lost in fractions (The Republic, VII, 525).
plurality of measures. (Thus it is natural that one is not a number; for the measure is not measures, but both the measure and the one are starting points). The measure must always be some identical thing predictable of all the things it measures, e.g., if the things are horses, the measure is ‘horse’, and if they are men, ‘man’. (Metaphysics, 14,1088\textsuperscript{a}, 3-10).

Aristotle believed continuous quantities to be composed of unit parts that shared common boundaries:

A line, on the other hand, is a continuous quantity, for it is possible to find a common boundary at which its parts join. In the case of the line, this common boundary is the point; in the case of the plane, it is the line: for the parts of the plane have also a common boundary. Similarly, you can find a common boundary in the case of the parts of a solid, namely either a line or a plane (Categories 6, 5\textsuperscript{a}, 5).

There are no gaps, spaces, breaks or voids within instances of continuous quantities as their constituent ‘parts’ are joined seamlessly. These Aristotle termed the primary quantities. All other continuous quantities are secondary quantities in that their quantitative nature is expressed in reference to primary quantity; hence, secondary quantities are manifested behaviours of primaries. He argued:

For instance, should anyone explain how long an action was, his statement would be made in terms of the time taken, to the effect that it lasted a year, or something of that sort... Thus the things already mentioned, and these alone, are in their intrinsic nature quantities; nothing else can claim the name in its own right, but, if at all, only in a secondary sense (6, 5\textsuperscript{b}, 5-10).

Number, a discrete quantity, could be applied to continuous quantities if one held to the following. According to Aristotle, continuous quantities were also multitudes of units, but given that these quantities are continuous, no arguments concerning the indivisibility of these particular units could be advanced. Given, however, that any continuous quantity could be divided into unit parts of identical magnitude, or aliquot parts, the application of whole numbers to continuous quantities was possible. In more formal terms, \( a \) is an aliquot part of a magnitude \( b \) if and only if there exists a positive whole number \( w \) such that \( b = wa \). Aristotle argued:

‘The One’ evidently means a measure. And in every case there is some underlying thing with a distinct nature of its own, e.g. in the scale a quarter tone, in spatial magnitude a finger or foot or something of the sort... (Metaphysics, XIV,1,1087\textsuperscript{b}, 33-36).

The rational and irrational numbers clearly had no place in the number theory of the ancient Greeks. Yet Aristotle was very well aware of the problem which existed if two unit lengths were placed at right angles to each other, the hypotenuse of the resulting triangle will always be incommensurable with the unit sides. That is, the unit length can never be an aliquot part of the hypotenuse magnitude which it creates. Thus the ratio
between the unit magnitude and the hypotenuse cannot be a natural number. It is, indeed, an irrational number in the form of the surd $\sqrt{2}$ of the unit. Aristotle commented:

For all men begin, as we said, by wondering that things are as they are,... [such as] the incommensurability of the diagonal of a square with the side; for it seems wonderful to all who have not yet seen the reason, that there is a thing which cannot be measured even by the smallest unit. But we must end in the contrary and, according to the proverb, the better state, as is the case in these instances too when men learn the cause; for there is nothing which would surprise a geometer so much as if the diagonal turned out to be commensurable (Metaphysics, I, 2, 983a, 11-20).

This was the extent of Aristotle’s analysis of quantity. Having established quality and quantity as equally real yet structurally different phenomena, he delivered only a sketchy and incomplete picture of the nature of quantity. Aristotle had introduced a degree of reification in his analysis of continuous quantity - naming examples of such rather than analysing the concept of continuity. Although briefly introducing the concept of measurement, he failed to develop the pertaining arguments, as perhaps he was unaware of the significance of this concept. Although knowledgeable of the standard measurements used at this time, such as the cubit, Aristotle did not write on the philosophical processes with which such measures come into existence. This task was left to another of the great ancient Greek intellectuals.

1.2 Euclid of Alexandria

Euclid of Alexandria (c.fl.300 BC) was a lecturer and scholar of mathematics at the university in Alexandria during the 306 - 283 BC reign of Ptolemy I (Boyer, 1968). Like Aristotle, Euclid was not able to solve the problem of the incommensurability of the diagonal of the unit square; the consequent problem of the non-ratio (irrational) numbers; nor could he give an adequate account of continuous quantity. Euclid did, however, provide the intellectual base upon which these seemingly intractable problems were solved in the late nineteenth century by the great German mathematician Richard Dedekind (1872,1963). This intellectual base was Euclid’s text, the Elements.

Book V of the thirteen Books of the Elements contained the first formal presentation of the general nature of measurement and of quantitative structure. It is possible that the Elements is a compilation and that Book V is the work of Eudoxus of Cnidus (fl.c.400BC) (Birkhoff & MacLane, 1965; Stein, 1990). Nevertheless, this first attempt to delineate the structure common to all quantitative attributes differed sharply from Aristotle’s taxonomy of primary and secondary quantities. What Michell (1990, 1999)
terms the classical theory of measurement was first formally advanced within the first 10 definitions. These are presented below (Heath, 1952, p.81, original emphasis):

1. A magnitude is a part of a magnitude, the less of the greater, when it measures the greater.
2. The greater is a multiple of the less when it is measured by the less.
3. A ratio is a sort of relation in respect of size between two magnitudes of the same kind.
4. Magnitudes are said to have a ratio to one another which are capable, when multiplied, of exceeding one another.
5. Magnitudes are said to be in the same ratio, the first to the second and the third to the fourth, when, if any equimultiples whatever be taken of the first and third, and any equimultiples whatever of the second and fourth, the former equimultiples alike exceed, are alike equal to, or alike fall short of, the latter equimultiples respectively taken in order.
6. Let magnitudes which have the same ratio be proportional.
7. When, of the equimultiples, the multiple of the first magnitude exceeds the multiple of the second, but the multiple of the third does not exceed the multiple of the fourth, then the first is said to have a greater ratio to the second than the third has to the fourth.
8. A proposition in three terms is the least possible.
9. When three magnitudes are proportional, the first is said to have to the third the duplicate ratio of that which it has to the second.
10. When four magnitudes are [continuously] proportional, the first is said to have to the fourth the triplicate ratio of that which it has to the second, and so on continually, whatever be the proportion.

With Definitions 1 and 2, Euclid attempted to define the concept of magnitude. However, he did so tautologically. To define a magnitude as a part of a magnitude is equivalent to defining $p$ as a part of $p$; which tautologous as nothing new about $p$ is known. It follows that any natural phenomenon cannot be defined if it is argued to be a part of the very natural phenomenon of which a definition is being sought. There are two probable interpretations that can be made of these Definitions. Firstly, that Euclid was attempting to define the unit magnitude and to explicitly state that such a magnitude was of the same kind as the magnitude being measured. Secondly, that in stating a magnitude being a part of another magnitude, Euclid was arguing that there is no greatest magnitude. Stein (1990) states that the lack of clarity of these Definitions can be attributed to Euclid considering the concept of magnitude to be self-evident and obvious. There could, however, be something more here.

Definitions 1 and 2 are virtually identical to Definitions 3 and 5 of Book VII. In Book VII, the definition of whole numbers as parts of whole numbers is not non-sensical as number is considered a discrete quantity. Hence a unit number is a sense-datum in that it

---

2 Aliquot parts
is easily perceived as a one-membered aggregate of any spatiotemporally located object. For example, any aggregate of bulldozers can be demonstrated to consist of \( n \) bulldozers, \( n \) being any finite whole number, given that the unit, 1 bulldozer, can be easily identified as such because objects are easily comprehended. On the other hand, unit magnitudes or parts of continuous quantities are not sense data as the immediate identification of a magnitude as of an exact extent is not within the limitations of human perception and is thus impossible (Michell, 1997a). Euclid appeared to ignore this fact as he wrote as if magnitudes of continuous quantities were sense data. It is doubtful, however, that he actually believed this to be the case as he did attempt to apply the division algorithm to the incommensurables in Book X. That magnitudes are not sense data must have posed a difficult problem for Euclid, or else he would not have tried to avoid it by making the aforementioned Definitions of Book V and VII so similar.

Definition 3 is where Euclid gives his famous definition of the ratio. Cognisant of the fact that both commensurable and incommensurable magnitudes of continuous quantities sustained ratios as per Book X, Euclid deliberately did not specify exactly what type of relation the ratio was. Euclid's tautologous definition of magnitude did not assist matters. Consequently, Euclid has been accused as being so vague here that his definition is almost useless (Boyer, 1968); this vagueness manifest in Definition 3 with the ratio being a 'sort' of relation 'in respect to size'.

Definition 4 is quite often called the Archimedean condition\(^3\) by some scholars (e.g. Boyer, 1968; Stein, 1990). What this axiom asserts is that if any two magnitudes of a continuous quantity are taken, the result of their multiplication will always be greater than either of the two initial magnitudes. Given that an infinite number of pairs of magnitudes can be taken, it follows that there will always be a magnitude greater than either. No continuous quantity possesses an infinitely greatest magnitude.

But it is in Definition 5, with the support of Propositions 8, 9 and 10 that the real power of the classical theory of measurement is contained. This Definition is the famous theory of proportion of ratio; which Michell (1999, p.28) argues: “....is one of the greatest intellectual triumphs of all times.” The theory of proportion of ratio argues that for any ratio between two continuous magnitudes there exists another ratio between two other magnitudes which is identical to it. If we take the ratio of two magnitudes \( x:y \) and another

\(^3\) Archimedes of Syracuse (c.287 - 212BC) wrote that: “Further, of unequal lines, unequal surfaces, and unequal solids, the greater exceeds the less by such a magnitude as, when added to itself, can be made to
between two other magnitudes \( w:z \), the theory of proportion states that for all pairs of positive whole numbers \( a \) and \( b \), \( xy \) and \( w:z \) are identical if and only if (iff) either, but not all, of the following hold:

\[
\begin{align*}
& a/ \ ax \leq by \iff aw \leq bz \quad (\text{for ratios}, \ x:y < a:b \iff w:z < a:b) \\
& b/ \ ax = by \iff aw = bz \quad (\text{for ratios}, \ x:y = a:b \iff w:z = a:b) \\
& c/ \ ax \geq by \iff aw \geq bz \quad (\text{for ratios}, \ x:y > a:b \iff w:z > a:b) \quad (\text{Michell, 1999; Rusnock \& Thagard, 1995}).
\end{align*}
\]

What these conditions mean is that two ratios of continuous magnitudes are identical when both are either equal, less or greater than the positive whole number ratios. Thus Definition 5 divides the class of all possible ratios into three mutually exclusive classes. If the ratios are equal, then only the class of condition \( b/ \) is non-empty. If the ratios are not equal, then this class is empty and one and only one of the other two classes, those specified by conditions \( a/ \) and \( c/ \), is non-empty and exhaustive. Note that each of these classes contain an infinite number of inequalities and that each class is mutually exclusive and disjoint. That is, they do not share one ratio in common (Michell, 1999).

1.3 Definition of the classical theory of measurement

A modern definition of the Euclidean theory of measurement has been recently advanced: Measurement is the discovery or estimation of the numerical relation (ratio) between a magnitude of a continuous quantitative attribute and a unit magnitude of the same kind (Michell, 1990, 1997b, 1999). If \( x \) is a magnitude of a continuous quantitative attribute whose size is unknown, and \( y \) is a unit magnitude of known size, no matter if the magnitudes are commensurable or incommensurable, a real number \( r \) is always instantiated by the ratio between \( x \) and \( y \), such that \( r = \frac{x}{y} \) and \( x = ry \). For any kind of continuous quantitative attribute, the theory of proportion of ratio applies. That is, if the ratio \( x:y \) is taken another ratio \( a:b \) is taken between two magnitudes of the same quantitative attribute that \( x:y \) pertains, and for all pairs of the positive real numbers \( r \) and \( s \), \( x:y \) and \( a:b \) are identical iff either, but not all of the following hold:

\[
\begin{align*}
& j. \ rx < sy \iff ra < sb \quad (\text{for ratios}, \ x:y < r:s \iff a:b < r:s) \\
& k. \ rx = sy \iff ra = sb \quad (\text{for ratios}, \ x:y = r:s \iff a:b = r:s) \\
& l. \ rx > sy \iff ra > sb \quad (\text{for ratios}, \ x:y > r:s \iff a:b > r:s)
\end{align*}
\]

A quantitative attribute is "a range of mutually exclusive properties (such as all possible lengths) or a range of mutually exclusive relations (such as all possible exceed any assigned magnitude among those which are comparable with [it and with] one another" (On the Sphere and Cylinder, Book I, Assumption 5).
velocities)..." (Michell, 1995:p.244). Quantitative attributes differ from non-quantitative attributes in the possession of *additive structure*. Only quantitative attributes possess additive structure, hence only quantitative attributes can sustain ratios. Therefore, the discovery of a ratio indicates that a particular attribute is quantitative.

Differing from Aristotle, objects *possess* quantitative attributes, the objects themselves are not quantities. Initially, it is presumed there is no limit to the number of quantitative (or non-quantitative) attributes an object can possess unless previous observations suggest otherwise. Each quantitative attribute, following Aristotle’s observation, can be of only one magnitude at any given moment. A *magnitude* is an instance of a continuous quantitative attribute whose exact size is not a sense datum. Consequently, the *unit magnitude* is a precisely specified, but never perfectly ascertained, magnitude of the same kind. The unit magnitude is therefore always arbitrary in that it must be humanly manageable; making allowance for the limitations of human cognition (Michell, 1999).

Given that magnitudes are always imperfectly known, ratios are always imperfectly estimated. Error always accompanies a ratio. This is not to say that ratios cannot sometimes be precisely estimated. Measurement always advances with the increasing accuracy of the estimations made of ratio values, but increasing accuracy does not ever eradicate the possibility of error. This is why measurement involves the instantiation of *real* numbers by the infinite number of possible pairs of magnitudes. In measurement the real numbers are never completely known, only estimated. This is an extremely important departure from Euclid, who thought that ratios cannot be *instantiations* of the whole numbers, the only numbers thought to exist at that time. For Euclid, the ratios of commensurable magnitudes could only be *identified* with the ratios between the whole numbers. This having been said, the classical theory of measurement does maintain one vital tenet of Euclid. And that is, numbers are not productions of the human mind, they are real, spatiotemporally located relations. Why this is important to the classical theory is that any laws derived to explain the causal mechanisms underpinning the behaviours of any quantities can be interpreted realistically. That is, as statements of things as they actually exist (Michell, 1997b).

1.4 The presence of the classical theory of measurement in the physical sciences

Michell (1999) contended that whilst physics texts rarely give a definition of measurement, when they do it is always the classical. To test this contention, I undertook

---

a survey of randomly selected introductory physics textbooks in the undergraduate section of the Fischer Library of the University of Sydney.\textsuperscript{5} It was found that Michell's contention was true. Of the 28 texts surveyed, only 10 gave a definition of measurement. But of these texts, all advanced the classical theory as the theory of measurement. From 5 of them came the following:

To measure a physical quantity it is first necessary to choose a unit of that quantity, measuring the quantity then means comparing it with the unit or, stated in another way, finding the ratio of the magnitude of the quantity to that of the unit (Morgan, 1963:pp.6-7).

The measurement of any physical quantity involves comparing it with the same precisely defined unit value of that quantity. For example, to measure the distance between two points, we compare that distance with a standard unit of distance, such as the metre. The statement that a certain distance is "25 metres" means that it is 25 times the length of the unit metre. That is, a standard metre stick fits into the distance 25 times. It is important to include the unit “metre” along with the number “25” in expressing a distance because there are other units of distance, such as feet or miles, in common use. To say that a distance is 25 is meaningless. The magnitude of any physical quantity must include both a number and a unit (Tipler, 1991:p2).

The magnitude of a physical quantity is specified by a number and a unit (Shortley & Williams, 1971:p.4).

A certain standard quantity of some kind, called a unit, is first established, and other quantities of the same kind are compared with it. When we say a ladder is 2.6 metres long, we mean that it is 2.6 times a certain distance called the metre whose magnitude is fixed by international agreement. The result of every measurement must therefore have two parts, a number to answer the question “How many?” and a unit to answer the question “Of what?” (Beiser, 1982).

Every measurement whether it be a distance, a weight, an interval of time, or anything else, requires two things: first, a number; and second, a unit (White, 1940:p.13).

Hence the Euclidean theory of measurement is still argued as true in the discipline of physics, the undisputed paradigm of quantitative science (Michell, 1997b), upon which the less successful quantitative sciences, such as psychometrics, have unashamedly modelled themselves. That any scientific theory is held true 2,500 years after its inception is a remarkable achievement, a feat unparalleled by any other scientific theory, including Euclidean geometry.

\textsuperscript{5} A reference list of this survey appears in Appendix 13.
That 18 of the texts surveyed did not mention a theory of measurement in no way invalidates the above argument. It was found that 24 of the texts mentioned the importance of both the precise instantiation of unit magnitudes of physical quantities and the standardisation of such magnitudes. As these are only logically entailed by the classical theory of measurement, it can be safely argued that the authors of these texts held the classical theory as true, but for some reason did not mention it. Perhaps because as one of them said: “Metrology, the science of accurate measurement, is not everybody’s meat, and appeals only to certain types of mind” (Reimann, 1971:pp9-10). Only 2 texts did not mention anything of measurement, both starting with vector algebra and dimensional analysis. Thirteen mentioned the latter theory, it being a further abstraction upon Campbell’s (1921, 1957) theory of derived measurement (Krantz, Luce, Suppes & Tversky, 1971). Additionally, 6 texts mentioned Campbell’s theory.

Why physics advances the truth of the classical theory of measurement is no unfathomable secret. It enables an empirical test of any attribute for the presence of additive structure. It is also the most parsimonious theory of measurement. Most importantly, it locates the rational numbers firmly in the spatiotemporal realm as the relations between magnitudes of continuous quantities. Thus it allows for what is known as the empirical realist theory of number (Forrest & Armstrong, 1987; Michell, 1993; Niederee, 1987) which is advocated by theoretical physicist Stephen Hawking:

> The laws of science, as we know them at present, contain many fundamental numbers, like the size of the electric charge of the electron and the ratio of the masses of the proton and the electron. We cannot, at the moment at least, predict the values of these numbers from theory - we have to find them by observation. It may be that one day we shall discover a complete unified theory that predicts them all, but it is also possible that some or all of them vary from universe to universe or within a single universe. The remarkable fact is that the values of these numbers seem to have been very finely adjusted to make possible the development of life (1988:p.125).

Hence the experimental observation and estimation of ratios is absolutely critical to a correct understanding of the quantitative structures present in the universe.

1.5 Additivity summarised: The axioms of Otto Hölder (1901)

Nevertheless, the classical theory of measurement was not fully developed until the latter half of the twentieth century; its key weakness being that it only held true directly in its Euclidean form to extensive quantities. As science had advanced enormously over the past 2,500 years, it was understood by the early twentieth century that not all
quantities were geometric. Furthermore, what was meant by ‘additivity’ was not well understood.

Otto Ludwig Hölder (1901), a measurement theorist and Professor of Mathematics at the University of Leipzig, published a paper titled “Die Axiome der Quantitat und die Lehre vom Masse”. This paper gave birth to modern measurement theory. Narens & Luce (1986) argue that Hölder’s most important contribution was the concept of the Archimedean ordered mathematical group; a concept which flowed from his famous theorem.

In Part I of his paper, Hölder set down axioms for the additive structure of quantitative attributes. For the first time in history were the laws governing additive structure explicitly stated. These axioms formed Hölder’s main theorem in which Euclidean ratios were isomorphic to the real numbers. The arguments concerning the Archimedean ordered group were in the footnotes of Part 1 (Michell & Ernst, 1986). But most importantly for quantitative psychology, Part 2 of the paper established that additive structure can be identified indirectly through the observation of line intervals. It was this development which anticipated the breakthrough of the conjoint theory of measurement (Luce & Tukey, 1964) over six decades later. To bring this vital paper to the attention of quantitative psychologists, Michell & Ernst (1996, 1997) published a two part English translation in the Journal of Mathematical Psychology. It is from this work that the following is garnered.

Hölder argued that a theory of the additive structure of quantitative attributes could only be developed through the observation of such attributes; as how Euclid had derived the axioms of geometry from observation. Hölder called such a theory “...the theory of measurable magnitudes..... based upon a set of facts which I will call ‘axioms of magnitude’ or ‘axioms of quantity’ (p.237). It must be stated here that Hölder cautioned against interpreting that such axioms are immediately pertinent to geometric attributes. Instead, Hölder argued that such axioms follow from Euclid’s definitions of lines in Book I of the Elements, and are applicable in a similar way to time and mass.

Although crediting Euclid for advancing measurement theory “...to a high level” (p.238), Hölder was disappointed with subsequent attempts to rectify limitations and explore obscurities in Euclid’s theory. Thus Hölder argued “...a reformation of this important and fundamental theory will be profitable (p.238)” and consequently expounded his axioms of magnitude (taken verbatim from Michell & Ernst, 1996, p.238):
The axioms of quantity, i.e the facts upon which the theory of magnitudes (absolute) quantities is based, are as follows:

I: Given any two magnitudes, \(a\) and \(b\), one and only one of the following is true: \(a\) is identical to \(b\) (\(a = b\), \(b = a\)), \(a\) is greater than \(b\) and \(b\) is less than \(a\) (\(a < b, a > b\)), or inversely \(b\) is greater than \(a\) and \(a\) is less than \(b\) (\(b > a, a < b\)).

II: For every magnitude there exists one that is less.

III: For every ordered pair of (not necessarily distinct) magnitudes, \(a\) and \(b\), their sum, \(a + b\), is well defined.

IV: \(a + b\) is greater than \(a\) and greater than \(b\).

V: If \(a < b\), then there exist \(x\) and \(y\) such that \(a + x = b\) and \(y + a = b\).

VI: It is always true that \((a + b) + c = a + (b + c)\).

VII: Whenever all magnitudes are divided into two classes such that each magnitude belongs to one and only one class, neither class is empty, and any magnitude in the first class is less than each magnitude in the second class, then there exists a magnitude \(\xi\) such that every \(\xi' < \xi\) is in the first class and every \(\xi'' > \xi\) belongs to the second class. (Depending on the particular case, \(\xi\) may belong to either class).

With Axioms I & II, Hölder fleshed out Euclid’s (Def.s 1 and 2, V, Elements) skeletal description of the concept of magnitude. Any two magnitudes (or instances of a quantity) can only be either equivalent (a commutative relation) or ordered (an asymmetric relation with one magnitude of the pair being greater than the other). Thus Axiom I is the famous ‘law of trichotomy’ (Stein, 1990). According to Michell (1999), Hölder was the first to demonstrate that an attribute hypothesised to be quantitative could be ascertained as such through the observation of manifested order and equivalence relations of its constituent magnitudes.

Axioms IV and V require that the attribute be additively complete; although in the case of velocity Axiom IV cannot hold. With Axiom V Hölder was being overly cautious with his inclusion of element \(\gamma\) which actually does not need to be explicitly stated for the Axiom to hold. Nevertheless, Axiom V formalises the requirement that if one magnitude (\(a\)) is less than another (\(b\)) then there must exist another (\(c\)) combined with \(a\) so that \(a\) equals \(b\).

Axiom VI is the associative law. It requires that if different combining operations on three magnitudes are performed the results will always be equivalent.

Axiom VII is Hölder’s requirement that a quantity be Dedekind complete, i.e continuous. If we take the class of all possible length magnitudes and divide them into two groups, the first being less than two metres and the second greater, in order for there not be a gap between the classes the length magnitude of two metres must exist. The second class of lengths are the upper bounds of the first then the two metre magnitude is
the least upper bound of the first class. Thus magnitudes are Dedekind cuts of quantities
in the same way as the real numbers are of the real number system.

If the elements of a particular attribute are observed to obey all of Hölder’s axioms then
that attribute can be considered to possess additive structure and is thus quantitative. If
Axiom VII holds (it may not hold for all observed quantities) the ratios of between the
magnitudes of that quantity will be isomorphic to the system of the real numbers.

Hölder demonstrated that given solvability and association (Axioms V and VI,
respectively), magnitudes of continuous quantities are always transitive. That is, if there
exists magnitudes \( a, b, \) and \( c \), if \( a < b \) and \( b < c \), therefore \( a < c \). To enable \( a < c \) Hölder
argued of the existence of the converse to Axiom II such that for every magnitude \( (a) \)
there exists one \( (c) \) that is greater than it. Establishing transitivity, Hölder argued that for
magnitudes \( x < x' \) and \( y < y' \) that \( x + y < x' + y' \), such that lesser magnitudes
added to lesser magnitudes gives lesser magnitudes. This argument is very similar to the
Thomsen condition of axiomatic conjoint measurement (Krantz, et al, 1971).

Hölder also demonstrated that for any attributes of which the magnitudes obeyed his
Axioms, it logically followed that the attribute was also Archimedean, such that for any
two magnitudes \( a \leq b \) there exists an integer \( n \) such that \( na > b \). He also stressed in a
footnote to this section that the Archimedean condition was different to Dedekind’s
(Axiom VII):

> The comment that the Archimedean axiom is “contained” in Dedekind’s axiom of continuity
could lead to misunderstandings. I emphasise that the Archimedean axiom can be deduced
from Axiom VII aided by axioms I to VI, but only via the proof given in the text or
something similar, which is why such a proof is by no means superfluous (Michell & Ernst,

Thus the Archimedean condition holds as a consequent of an attribute being
quantitative. The arguments Hölder presented to support his statement are collectively
known today as Hölder’s theorem. The theorem states that any Archimedean ordered
mathematical group is isomorphic to a subset of the real numbers; this subset consisting
of the positive reals only. It is Hölder’s arguments concerning the Archimedean ordered
group that formed the basis of recent investigations into a general, non – geometric
theory of additivity.

1.6 Additivity generalised: The Archimedean ordered group of translations (Luce,
1987).
The problem of a general theory of quantity was one that was not solved until relatively recently. The mathematical psychologist and representational measurement theorist R. Duncan Luce (1986, 1987, 2001; Luce, et al, 1990) solved this problem by finding that Hőlder's theorem held not at the structural level of the attribute but at the level of its automorphisms.

Luce began with a general definition of a quantitative attribute. A *weakly ordered relational structure* is of the form \( X = \{X, \succ, S_0, S_1, \ldots, S_J\} \) where "\( \succ \)" is a weak order on \( X \) (ie it is transitive and strongly connected), \( X \) is the *domain of discourse* of \( X \) or the set of objects to which the particular ordered relational structure pertains\(^6\); and \( S_j \) are the primitive relations that define \( X \), where \( J \) is a finite sequence of integers and \( j \in J \).

Citing Cohen & Narens (1979), Luce (1987) argued that some ordered relational structures have an isomorphic relationship with sets of positive real numbers Luce called *real unit structures*. Such relational structures Luce called 1-point homogeneous *positive concatenation structures* (PCS); structures that obey all of Hőlder's (1901) axioms. Luce (2001) contended that only these structures have repeatedly empirically supported ratio scale measurement. Luce argued that the ratio scalable facility of PCSs resides in the class of non-fixed automorphisms of any PCS forming an Archimedean ordered mathematical group under function composition. The said automorphisms have an Archimedean ordering as Luce stated that they *do not cross.* What this means is that given any two automorphisms, \( \alpha \& \beta \in A \), \( A \) being the automorphism set of \( X \); and for all objects \( x, y \in X \), \( \alpha(x) \succ \beta(x) \) iff \( \alpha(y) \succ \beta(y) \) and \( \alpha(x) \sim \beta(x) \) iff \( \alpha(y) \sim \beta(y) \). The Archimedean ordering "\( \succ \)" of \( A \) can be defined for \( \alpha, \beta \in A \): \( \alpha \succ \beta \) iff for some \( x \), and hence all \( x \), \( \alpha(x) \succ \beta(x) \). Thus no automorphism in \( A \) is infinitely greater than any other in \( A \).

This argument, however, does not include the *degenerate* automorphism of \( A \). The degenerate automorphism is also known as the *identity* automorphism and has a fixed point. This means that for any such automorphism \( \tau \in A \), \( \tau(x) = x \) for all \( x \in X \). When this fixed automorphism is included in the class of the non-fixed automorphisms, the automorphisms are known as *translations*. Luce (1987, Theorem 2.1 & 2.2) argued that for \( X \) with its set of translations \( T \), if either \( T \) is a 1-point homogeneous and commutative

\(^6\) If unfamiliar with sets and representationalism, read sections 1.9 and 1.10 of this chapter. A definition of the concept of automorphism is in Chapter 2, section 2.9.
mathematical group or $X$ is order dense and Dedekind complete, then the translations of $T$ also do not cross like the automorphisms of $A$. If the translations of $T$ do not cross, then $T$ is an Archimedean ordered group.

Here we must digress from Luce and define what is meant by a mathematical group. Essentially, a group is a particular structure that is formed by the elements of a given class. More precisely, Birkhoff & MacLane (1965, p.98) state that: “A group $G$ is a system of elements which is closed under a single-valued binary operation which is associative, and relative to which $G$ contains an element satisfying the identity law, and with each element another element (called its inverse) satisfying the inverse law.”

This means that if we take the set of translations $T$ of an ordered relational structure $X$, then for the non-fixed automorphisms $q,r,s \in T$ and the identity automorphism $\tau \in T$, the following three laws hold iff $T$ is a group:

- **Associative law:** $q(rs) = (qr)s$ for all $q,r,s \in T$
- **Identity law:** $q\tau = \tau q = q$ for all $q \in T$
- **Inverse law:** $qq^{-1} = q^{-1}q = \tau$ for each $q \in T$ and some $q^{-1} \in T$ (Birkhoff & MacLane, 1965).

The satisfaction of the three above laws by the elements in $T$ make $T$ a mathematical group. Any group is necessarily a quantitative structure.

Luce (1987) proceeded to go into detail of the types of Archimedeaness in the different sequences that elements of $X$ may form. This is not the place to examine this, however, Luce (1987, Corollary to Theorem 3.3) concludes that if $X$ is a totally ordered concatenation structure, $X$ sustains a real unit structure in the class of the positive real numbers and the four types of Archimedeaness are sustained. But Luce then wondered how Archimedeaness can be related back to the general structure of $X = \langle X, >, S \rangle_{i \in I}$ mentioned earlier. Luce stated that a possible answer to this can be found in those structures which sustain Archimedean ordered groups of translations.

First, Luce generalised the concept of a unit structure as that whose elements can be multiplied by a positive constant. These positive constants are actually translations, so that for translations $t, s, r$ the functional equation $tr \odot ts = t(r \odot s)$ holds. Luce then argued that the task is to generalise this to general structures whose translations are multiplication by constants.
Luce (1987, Definition 4.1) argued that a real relational structure in the real numbers \( R = \{ R_j \}_{j=1} \) is a real unit structure as per Cohens & Narens (1979, cited in Luce, 1987) iff \( R \subseteq \mathbb{R}^+ \) and there is some \( T \subseteq \mathbb{R}^+ \) ("\( \subseteq \)" denoting 'is a subset of') such that:

1/ \( T \) is a mathematical group under function composition

2/ \( T \) maps \( R \) into \( R \) such that for each \( r \in R \) and \( t \in T \), \( tr \in R \)

3/ \( T \) restricted to \( R \) is the set of translations of \( R \)

Luce argued that form 1/ and 2/ and \( T \subseteq \mathbb{R}^+ \) the translations of a real unit structure form an Archimedean ordered group. That each \( t \in T \) is actually an automorphism implies that each element in \( R \) can be multiplied by it. This means for each \( R_j, j \in J \), \( r_i \in R_j, i = 1, \ldots, n(j) \) and \( t \in T \), if \( (r_1, \ldots, r_{n(j)}) \in R_j \), then \( (tr_1, \ldots, tr_{n(j)}) \in R_j \).

However, any real unit structure must be Dedekind complete. Luce (Theorem 4.1, p.176) stated:

"Suppose \( R = \{ R_j \}_{j=1} \) is a real unit structure with \( T \subseteq \mathbb{R}^+ \) its group of translations:

i/ Then \( R \) can be densely imbedded in a Dedekind complete unit structure, \( \mathbb{R}^+ \).

ii/ If \( R \) is order dense in \( \mathbb{R}^+ \), then each automorphism of \( R \) extends to an automorphism of \( \mathbb{R}^+ \).

iii/ If \( T \) is [1-point] homogeneous and \( R \) is order dense in \( \mathbb{R}^+ \), then \( \mathbb{R}^+ \) of part ii/ is on \( \mathbb{R}^+ \) and \( T^* \) is [1-point] homogeneous."

Thus the translations in \( T^* \) are Dedekind complete and thus \( T^* \) is continuous.

Luce then finalised his argument for relational structures in Theorem 5.1 (p.177):

"Suppose \( X = \{ X, \succ, S \} \) is a relational structure, \( T \) is its set of translations, and "\( \succ \)" is the asymptotic ordering of the automorphisms. Let * denote function composition. Then the following are equivalent:

i/ \( X \) is isomorphic to a real unit structure with a [1-point] homogeneous group of translations.

ii/ \( \langle T, \succ, * \rangle \) is a [1-point] homogeneous, Archimedean ordered group.

iii/ \( T \) is 1-point unique and there exists an Archimedean, solvable conjoint structure \( C \) with a relational structure \( X \) on the first component such that \( X' \) is isomorphic to \( X \) and \( X' \) distributes in \( C \).

Corollary 1. the conjoint structure of part iii/ satisfies the Thomsen condition."

Thus continuous, quantitative attributes form, under function composition, commutative, 1-point homogeneous and Archimedean ordered mathematical groups of translations and that the elements of continuous, quantitative attributes are isomorphic to real unit structures in the system of the real numbers which also sustain 1-point homogeneous mathematical groups of translations. In other words, any empirical
relational structure whose translations form an Archimedean ordered group causes the positive real numbers to also display translations which form such a group. Hence numerical arguments can be made of such ERSs. For the representationalists, this is how the real numbers find their way into measurement.

If a translation group is complex enough to be Archimedean ordered, it follows that the ERS must be of equal complexity. Hence it’s magnitudes must satisfy Hölder’s theorem and so hence must sustain ratios. Indeed, Michell (1990) demonstrates that ratios are extensionally equivalent to translations. That is, the class of all possible ratios sustained by any two magnitudes of any continuous quantity, such as length, also form a 1-point homogeneous, Archimedean ordered mathematical group. Michell (1990) argues that for any ordered relational structure $X = \langle X, >, S \rangle_{s \in J}$ whose set of translations form such a group $T$, then for any elements $w, x, y, z \in X$, $w \geq x \geq y \geq z$ iff $s \geq t$; where $s, t \in T$ such that $s(x) = w$ and $t(z) = y$. Each $t \in T$ is an equivalence class of ratios such that for any $t \in T$, $t = \{ x / y | t(y) = x \}$.

This does not mean that quantities no longer need to be additive, they do. A general definition of ratios is needed for two reasons. Firstly, a quantitative attribute may not be amenable to the operation of linear concatenation, as the attribute may not be a geometric structure able to directly manifest additivity. Secondly, it ties in nicely with Michell’s (1994) arguments concerning the necessity of defining the concept of additivity in the measurement of a quantitative attribute. From Luce’s (1987) work, ratios emanate from the automorphic structure of a quantity as does the concept of additivity.

What does the phrase ‘concept of additivity’ mean? Importantly, the automorphisms of a continuous quantitative attribute are symmetries of the attribute (Luce, 1997). A symmetry is generally a one-to-one transformation of a geometric shape which preserves the distance between its points (Birkhoff & MacLane, 1965). For example, if a piece of paper was cut into the shape of an equilateral triangle, placed on a flat surface and rotated 120 degrees clockwise, such a transformation would result. If it was rotated 360 degrees, the identity motion would result, a degenerate symmetry. Each symmetry, or one-to-one transformation of a geometric shape onto itself forms a mathematical group (Birkhoff & MacLane). Like geometric shapes, quantities also have symmetries as the algebra of symmetry can be extended to any class of entities. The symmetries of a quantity are its non-fixed automorphisms and the identity automorphism is the degenerate symmetry.
That quantitative attributes are infinitely symmetrical reveals that ratios are much more complex entities than has been previously argued. If an attribute $Z$ is discovered as having Archimedean ordered groups of translations, then for any pair of elements $c, d$ for all elements $a, b, \ldots, n \in Z$, there exists no unique ratio (Michell, 1994). For any continuous quantity $Z$ there may be a great many differing relations of additivity upon $Z$.

Michell (1990, 1994) and Luce (1997) give an example of how in physics, the continuous quantity of velocity can be defined via two differing relations of additivity. In classical, Newtonian physics, velocity may be given as the simple equation $v = u + at$. If $v$ is the final velocity, $u$ is the initial velocity, $a$ is the rate of acceleration and $t$ is the time elapsed; $u$ can be taken as the product of the multiplicative inverse relation between a distanced traversed and a duration of time. The velocities of any two moving objects $h$ and $j$ may be calculated in this way. If $h$ is moving relative to object $i$ ($x$) and $j$ is moving in the same direction relative to $h$ ($y$), then the velocity of $j$ relative to $i$ may be expressed as the concatenation $x \circ y$. This equation predicts the behaviour of moving objects very accurately unless those objects are starting to approach the speed of light. Using Einstein’s formula, the velocity of $j$ relative to $i$ would be calculated thus:

$$v_j = (x + y)(1 + xc^{-2})^{-1}.$$

It is not well known outside of physics that Einstein’s velocities can be concatenated as argued by Newton. Using the above example, if the unit of velocity is that of light and $v_j = z$, then $f(z) = f(x) + f(y)$ iff $f(a) = \tanh^{-1}(a) = 1/2 \ln((1 + a)/(1 - a))$, where $\tanh^{-1}$ is the inverse hyperbolic tangent function (Krantz, et al, 1971; Michell, 1990). Hence there are two differing, but formally related, concepts of additivity of velocity, each of which will yield differing numerical estimates of the relation between $x$ and $y$. In general, if one is to measure a continuous quantitative attribute, the estimation of a ratio between two given magnitudes “...cannot then be devised independently of a commitment to a specific additive relation between elements of the quantity involved” (Michell, 1994b:p.404).

1.7 The real numbers as ratios and their properties

Ratios usually exist in the first instance as rational numbers which can be expressed as repeating and terminating decimal expansions (Edwards & Penney, 1982). If $A$ is a given magnitude and $B$ is a unit magnitude then the ratio exists as a quotient of two real numbers in the form of $A/B$ (Michell). Irrational numbers are those expressed as non-
terminating and non-repeating decimals of infinite size (Edwards & Penny, 1982). For example, $\pi$ is such a number, it being the ratio of the circumference and the diameter of the circle, $C = \pi D$. As it is irrational, its entire value can never be observed, so it is usually approximated to 2 (3.14) or 3 (3.142) decimal places. Such approximation, however, unavoidably introduces error into calculations made of relations between quantities. Ratios cannot be numerically expressed precisely if they are irrational (Michell, 1990). Hence such a ratio is approximated with a certain amount of error. Michell (1990:p.64) gives the inequality $r + e/2 \geq n/m \geq r - e/2$ where $r$ is a real number, $\geq$ is the relation ‘at least as great than’, $n/m$ is the rational number used for approximation and $e$ is the level of accuracy or error, which must be greater than 0. Improvements of measurement techniques in the physical sciences have lead to the better estimation of ratios, yet as Michell (1990:p.64) concluded: “In measurement, such rational approximation must be settled for: absolute accuracy is a myth”.

The real numbers are an ordered class of entities that contains the natural, whole, rational and irrational numbers and the integers. All are conventionally depicted using Hindu-Arabic symbols and can be geometrically displayed on the real number line (Edwards & Penney, 1982). Hence, the structure of the real number system is held by analogy to line geometry as axiomatised in Elements, Book I. A line is drawn and upon one constituent point, zero (0) is designated. Those entities with positive valance lie to the right of zero, those of negative to the left. The absolute value of each entity is the distance between itself and zero, expressed formally (Edwards & Penney: $|x| = x$ iff $x \geq 0$; $-x$ iff $x < 0$. Hence, it is always true that $|x| \geq 0$ and $|x| = 0$ iff $x = 0$ (Edwards & Penney). If the absolute value of $x$ is 0 if $x$ is indeed 0, then the algebraic structure to which $x$ belongs is known as an ordered integral domain (Birkhoff & MacLane, 1965). Such a structure has the following properties:

a/ Closure: In a class of real numbers $A$, if there exists $x$ and $y$ in $A$ then $x + y \in A$ and $xy \in A$.

b/ Uniqueness: In $A$, if $x = x'$ and $y = y'$ then $x + y = x' + y'$ and $xy = x'y'$.

c/ Commutativity: $x + y = y + x; xy = yx$.

d/ Associativity: $x + (y + t) = (x + y) + t; x(yt) = (xy)t$.

e/ Distributive law: $x(y + t) = xy + xt$.

f/ Zero condition: $x + 0 = x$ for all $x \in A$.

g/ Unity: there is an entity $1 \neq 0 \in A$ such that $x1 = x$ for all $x \in A$. 

20
h/ Additive inverse: \( x + b = 0 \) has a solution \( b \in A \).

i/ Cancellation: If \( w \neq 0 \) and \( wx = wy \) then \( x = y \).

These properties are very similar to those advanced for quantitative attributes, indeed, some of them are identical. An integral domain is actually derived from a more basic structure algebraic structure known as a commutative ring (Birkhoff \& MacLane, 1965). The two structures differ in that in a commutative ring it is not known whether the cancellation condition applies. An integral domain is ordered when condition a/ above is satisfied and also when the positive integers of an integral domain satisfy the law of trichotomy, which states that for an integer \( x \), one and only one of the following is true: either \( x \) is positive, or \( x = 0 \), or \(-x\) is positive (Birkhoff \& MacLane). An ordered integral domain is sufficient to explain the behaviour of the integers, the ordered pairs of whole numbers, but is not enough to explain the rational numbers. This is why an ordered integral domain can be expanded to form a field (Birkhoff \& MacLane, 1965; Murdoch, 1957). Fields are ordered integral domains which possess the following:

j/ Inverse entity: For each entity \( x \neq 0 \) an entity \( x^{-1} \) exists which solves the equation \( x^{-1}x = 1 \).

Fields also have the capacity over integral domains in that any equation of the form \( xt = y \) (\( x \neq 0 \)) can be solved in them. With the possession of all these properties, a field is closed under the basic arithmetic procedures of addition, subtraction, multiplication and division; as stated in condition a/ (Murdoch, 1957).

Still, these conditions do not explain the behaviour of all of the real numbers, including the irrationals. One must introduce here the idea that like continuous quantities, the real numbers are dense and continuous. Birkhoff \& MacLane (1965) state that all real numbers are limits of one or more sequences of rational numbers (ie are Dedekind cuts) if the following is satisfied:

k/ Density: For relations \( x < y \) for all \( x, y \in A \), there must exist a rational number \( a / b \in A \) so that \( x < a / b < y \).

Similarly with density, Dedekind completeness pertains to the real numbers; thus constituting what is known as a complete ordered field (Birkhoff \& MacLane, 1965):

l/ Dedekind completeness: The field \( A \) of real numbers is complete if for every non-empty subclass \( H \in A \) that has a lower bound has a least lower bound and every subclass \( G \in A \) that has an upper bound has a least upper bound.

The elements in a complete ordered field must also finally obey one familiar axiom:
m/ Archimedean condition: For the elements \( x > 0 \) and \( y > 0 \in A \), then there exists an integer \( n \) such that \( nx > y \).

These final conditions ensure that the real numbers are as seamless as continuous quantities so that there are no gaps, meaning that the irrational numbers are well accounted for.

1.8 The representational theory of measurement

The discovery of non-Euclidean geometries in the early nineteenth century by Nicolai Ivanovitch Lobachevsky (1793-1856) and G.F.B Riemann (1826-1866) dealt a severe blow to Euclid's Elements (Aleksandrov, 1965; Boyer, 1968). It was realised that as a consequence of the falsification of Euclid's parallel lines theorem, shapes drawn on curved surfaces must not follow the Propositions of Euclid. The Elements was gradually removed from the curricula and Euclidean measurement theory aroused philosophical suspicions given that Euclid had obviously written Book V with length, exemplified as straight lines, as the paradigm of quantity. The classical theory of measurement came under sustained attack from those outside of the physical sciences (Michell, 1999). Yet no critic successfully argued that non-Euclidean lines and shapes could not sustain ratios. Geodesics on curved surfaces still possess the additively structured attribute of length (Luce et al 1990 discuss this). Nevertheless, this did not stop the inappropriate forced retirement of the classical theory of measurement from the philosophy of science.

Michell (1999) states that the earliest definition of the representational theory of measurement came from the mathematician and philosopher Bertrand Russell (1897, 1903, 1924). Russell was influenced by the writings of the German philosopher F.G.W Hegel (Michell, 1997a); whose antirealist romanticism decried empiricism and the reality of the spatiotemporal universe, advocating instead a belief in a spiritual ‘whole’ (Russell, 1994)\(^7\). This and the decline of the Elements influenced Russell to establish that number was not a part of the spatiotemporal realm. In order to do this, he presented arguments against the idea of the real numbers being empirically instantiated by the ratios between magnitudes of continuous quantities. These arguments are complex and have been well covered by Michell (1997a, 1999) and so will not be examined here.

If the real numbers are not instantiated in the spatio-temporal realm via ratios, then numbers must enter into measurement via some human operation. Russell (1903) stated that this operation is the process of assigning numbers to the natural world in such a way
that the ordering of the natural system, given that quantity to Russell reduced to mere order, is reflected in the ordering of the numbers thus assigned. Russell (1903, p.176) wrote that:

Measurement of magnitudes is, in its most general sense, any method by which a unique and reciprocal correspondence is established between all or some of the magnitudes of a kind and all or some of the numbers, integral, rational, or real, as the case may be. In this general sense, measurement demands some one-one relation between the numbers and magnitudes in question — a relation which may be direct or indirect, important or trivial, according to circumstances.

Russell’s creation of the representational theory of measurement did not have an immediate impact. Other mathematicians of the time, such as Hölder (1901), were still publishing work on the arguments presented by Euclid. By itself, Russell’s theory did not influence quantitative practices within the natural sciences. This changed with the publication of the book *Physics: The Elements* by Robert Norman Campbell (1921, 1957). Campbell, a physicist and measurement theorist, was influenced by Russell who in turn influenced the modern representationalists.

In modern representational measurement theory, Russell’s (1903) idea of numbers as classes of classes has no presence. Instead, numbers are sets. A brief explanation of set theory must be presented as modern representational measurement theory is essentially the theory of homomorphisms between sets.

### 1.9 The real numbers not as ratios but as sets

The founder of transfinite mathematics Georg Cantor is credited with also founding formal set theory; something which apparently arose as an artefact of his investigations into trigonometric series (Steckin, 1965). The recasting of the real numbers as complex constructions out of the empty set as opposed to instantiations of Euclidean ratios has been termed by Narens (1981a, p.1) the “Platonic/Cantorian development of mathematics”. The critical appraisal and extension of this philosophy to scientific deliberations concerning measurement comprises the entirety of the interests of the adherents of the representational theory of measurement.

A set is an abstract mathematical concept that may in the first instance be mistakenly thought of as an aggregate of objects. It is argued by the mathematicians that many

---

7 Russell (1994, p.107) later came to reject Hegel’s views, arguing: “...as I myself believe almost all Hegel’s doctrines are false...”.

8 Russell (1903, p.176) added: “Since the numbers form a series, and since every kind of magnitude also forms a series, it will be desirable that the order of the magnitudes should correspond to that of the
everyday entities form sets, such as red cars or Alsatian dogs or Australian doctoral students in psychology (Peterson & Hashikasi, 1967). The concept of a set, however, extends much further than this. Sets also pertain to hypothetical entities, such as Martian organisms; and also to human abstractions, such as letters and numerals. Sets also extend to probabilities and include outcome spaces of events. Those individual entities that form sets are known as the elements of the set. Using set notation, the set of the odd numbers to 29 reads \( A = \{1, 3, 5, \ldots, 29\} \) where the dots indicate the continuation of the series to the whole number 29. The letter \( A \) denotes the set and the odd numbers to 29 are the elements of \( A \). Algebraically, the inclusion of elements in a set is denoted by \( \in \), such as \( 1 \in A, 3 \in A \) and so on.

Sets can be wrought from other sets. The union of two sets \( J = \{2, x, 31\} \) and \( K = \{5, x, y, 20\} \) is the set whose elements are those in either set or both; in this case \( J \cup K = \{2, 5, y, 20, 31\} \). The intersection of two sets \( L = \{a, b, c\} \) and \( M = \{b, c, d\} \) is the set containing the elements common to both \( L \) and \( M \) such that \( L \cap M = \{b, c\} \).

Sets also contain subsets. The set \( B = \{1, 3, 5, \ldots, 11\} \) is a subset of \( A \), denoted \( B \subseteq A \), as all elements of \( B \) are in \( A \). If there is the set \( C = \{1, 3, 5, \ldots, 41\} \) then \( A \) and \( B \) are the proper subsets of \( C \), denoted \( B \subset C, A \subset C \), as all the elements of both \( A \) and \( B \) are in \( C \) but not all the elements of \( C \) are in either \( A \) or \( B \).

Sets may be specified by describing a property common to all the elements contained in the set. The set \( A \) can be rewritten as \( A = \{x \mid x \text{ is an odd number between } 0 \text{ and } 29\} \) where \( \{\} \) means “given that”. The \( x \) symbol is called the variable, the set the domain of the variable and the specified property of the elements the condition upon the variable (Peterson & Hashikasi, 1967). The important empty set (denoted either by \( \{\} \) or \( \emptyset \) ) can be specified in this way. It can be safely assumed that the following is an empty set: \( X = \{x \mid x \text{ is a Martian organism on Earth}\} = \emptyset \). Sets whose intersection is the empty set are disjoint like the sets \( D = \{51, 52, 53\} \) and \( C \) such that \( D \cap C = \emptyset \). The empty set is presumed by mathematicians to exist everywhere. Its logical opposite is the universal set (denoted \( U \) ) which contains all possible elements of a set, such as the set of all psychology doctoral students is a universal set (Peterson & Hashikasi).

---

9 Steckin (1965) argued that the set is "...one of the basic primitive mathematical concepts and does not lend itself to an accurate definition" (p.5). Steckin thus preferred to illustrate rather than define the concept: "Set is the name for an aggregate, ensemble, or collection of things that are combined under a certain criterion or according to a certain rule. The concept of a set arises by abstraction." (p.5).
1.10 The current paradigm of scientific measurement: Foundations of Measurement Vol I (Krantz, Luce, Suppes & Tversky, 1971).

The representational theory of measurement is now the dominant and accepted theory of measurement within the philosophy of science. The development of this theory of measurement, following Russell, Campbell and others, culminated as an axiomatised, set theoretical theory in the three volume *magnum opus* called *Foundations of Measurement* (Krantz, Luce, Suppes & Tversky, 1971; Suppes, Krantz, Luce & Tversky, 1989; Luce, Krantz, Suppes & Tversky, 1990). The first chapter of Krantz et al (1971) clearly outlines the basic argument of the representational theory of measurement. All of the important developments that have occurred in measurement theory during the past 40 years have been conducted within a representationalist framework, such as the theory of additive conjoint measurement (Luce & Tukey, 1964), the Archimedean ordered mathematical group (Luce, 1987; Luce et al, 1990) and the possible empirical bases of Stevens’ (1946) theory of scale types (Narens, 1981a & b). An understanding of this framework is required if this important work is to be understood.

Krantz et al (1971) begin by defining the representational theory of measurement in as simple terms as possible; and in such a way that the influence of both Russell (1903) and Stevens (1946) is easily seen:

> When measuring some attribute of a class of objects or events, we associate numbers (or other familiar mathematical entities, such as vectors) with the objects in such a way that the properties of the attribute are faithfully represented as numerical properties (p.1).

Caution must be exercised here in interpreting the representational meaning of ‘attribute’. As set down by Russell and Stevens, the representational theory of measurement does not argue of attributes being classes of either mutually exclusive properties or mutually exclusive relations. Attribute means in the representational context distinctive ‘qualities’ or structures that ‘concrete’ objects or events possess (Suppes & Zinnes, 1963). Despite the terminology, the representational theory of measurement abhors the metaphysical presuppositions of the classical theory of measurement.

Numbers are definitely not argued to belong to the same realm as the quantities they can so accurately reveal. Numbers in the representational theory of measurement are argued to be mere human abstractions. There are various schools of thought concerning these particular abstractions, the main ones being logicism, formalism and intuitionism (Boyer, 1968; Michell, 1999). The representationalists argue that numbers do indeed possess certain structures as they form algebraic complete ordered fields (such as the real
and complex numbers) and are consequently closed under all arithmetic operations. But as numbers are just human abstractions, they can be applied for measurement purposes by the human operation of assignment. This is how numbers find their way into measurement.

To commence measurement, the representationalists argue that some ‘quality’ of the object or event must be identified. Generally, it is helpful if at least three elements of that ‘quality’ are also identified. Let three such elements be a, b & c. The ordinal structure of the ‘quality’ may now be examined. If \( a \succ b \succ c \), then a numerical assignment reflecting this order can be made iff \( \phi a \succ \phi b \succ \phi c \) (Krantz et al, 1971). If the elements of the ‘quality’ are amenable to the process of concatenation (linear combination) then any of the above three elements can be selected and several other elements of the same quality can be identified as being identical to that selected element, such that for example \( c \sim c', c \sim c'', c \sim c''' \). If they can be concatenated, then numbers can be assigned such that \( \phi (c \circ c') = 2\phi (c) \). As \( b \succ c \) this must be reflected in the assignment such that \( \phi (c \circ c') \succ \phi (b) \succ \phi (c) \). From the concatenation operation, a sequence of elements can be constructed and numbers assigned such that \( c, 2c = c \circ c', 3c = (2c) \circ c'', 4c, 5c, ..., Nc \) (Krantz, et al, 1971). Such a sequence of elements is known as a standard sequence based on c.

Given any ‘quality’ capable of yielding standard sequences, Krantz et al (1971) ask:

Given a comparison relation \( \succ \) and a concatenation \( \circ \), what assumptions concerning \( \succ \) and \( \circ \) are necessary and/or sufficient to construct a real-valued function \( \phi \) that is order preserving and additive...?(p.8).

In representational measurement theory, formal set theory is applied to natural attributes. Any ‘quality’ of an object or event that can be concatenated is designated an ‘empirical relational structure’ or ERS. Relational structures are the particular surface structures of objects or events. All the elements of any ERS form an ordered set, denoted \( \langle c, \succ, \circ \rangle \), as the elements stand in the binary relations of transitivity and asymmetry via the concatenation operation. A numerical relational structure of the real numbers is similarly denoted \( \langle \mathbb{R}, \succ, + \rangle \). A numerical assignment of \( \langle c, \succ, \circ \rangle \) into \( \langle \mathbb{R}, \succ, + \rangle \) is a homomorphism iff the numerical assignment \( \phi a, \phi b, \phi c \) is transitive, asymmetric and connected such that \( \phi a \succ \phi b \succ \phi c \) iff 1. \( \langle c, \succ, \circ \rangle \) is a standard sequence; 2. The numerical structure is additive with respect to the concatenation operation on \( \langle c, \succ, \circ \rangle \) such that
\( \phi(b \circ c) = \phi b + \phi c \). If the sequence satisfies the axioms of order and additivity as per Hölder (1901), the homomorphism into the real numbers is known as a representation theorem (Krantz, et al, 1971). If there exists a one – one homomorphism, or isomorphism\(^{10}\), between the elements of the ERS and the set of the real numbers, it is argued that the elements of the ERS set are countable, that is, all of the elements are enumerated by the real numbers (Steckin, 1965). The concept of the representation theorem is an example of the concept of countable sets.

In general terms, \( C = \langle C, \geq, R_0, R_1, ..., R_n \rangle \) is an empirical relational structure where \( R_0, R_1, ..., R_n \) are empirical relations upon the variable \( C \) that define the set \( C \), meaning that the elements of \( C, a, b, c \) stand in relation \( R_0, R_1, ..., R_n \). These finite \( n \)th order relations are known as the primitives of the empirical relational structure and denote the properties which constitute \( C \), the variable of the set. \( C \) is also known as the domain of discourse of \( C \). Essentially, \( C \) represents particular ‘concrete’ objects or events (Suppes & Zinnes, 1963) that pertain to the type of ERS represented by \( C \). For example, if \( C \) is an ERS capable of ratio scale measurement, then \( C \) can represent any of the fundamental and derived quantities of physics, such as length, time and plane angle. Much work has been conducted on empirical relational structures; and thus far only three have been discovered. These are Dedekind complete scalar structures; linear structures and monotonic structures (Narens, 1981a & b).

If \( X = \langle \text{Re}, \geq, S_0, S_1, ..., S_n \rangle \) is a numerical relational structure where the primitive relations \( S_0, S_1, ..., S_n \) define the real numbers, a homomorphism exists iff there is a real-valued function \( \phi \) on \( C \) taking \( C \) into \( \text{Re}, R_0, R_1, ..., R_n \) into \( S_0, S_1, ..., S_n \) and \( \circ \) into \( + \) such that \( \phi a, \phi b, \phi c \) stand in relation \( S_0, S_1, ..., S_n \) and \( a, b, c \) stand in relation \( R_0, R_1, ..., R_n \) (Krantz, et al, 1971). Such homomorphisms into the real numbers, argue the representationalists, are what most behavioural scientists and psychologists call ‘scales’. Any such scale or homomorphism is unique iff one element of \( C = \langle C, \geq, R_0, R_1, ..., R_n \rangle \) is chosen, \( g \), such that its representation is \( \phi g = 1 \). Another homomorphism of \( C = \langle C, \geq, R_0, R_1, ..., R_n \rangle \) may be constructed as another element \( j \) is selected such that \( \phi j = 1 \). If \( C = \langle C, \geq, R_0, R_1, ..., R_n \rangle \) can relate the homomorphisms by the positive similarities transformation

\(^{10}\) An example of an isomorphism is one which exists between the elements of the sets of Hindu Arabic and Roman numerals, such that \( 1 \leftrightarrow I, 2 \leftrightarrow II \) and \( 23 \leftrightarrow XXIII \) (Dubisch, 1965).
\( \phi g \to \alpha \phi j, \alpha > 0 \), then the representationalists argue that the empirical relational structure \( C = \langle C, \geq, R_0, R_1, \ldots, R_n \rangle \) is ratio scalable. For the representationalists, this is how quantities are discovered.

As a consequence of its set theoretical approach to measurement, the results of representational measurement are interpreted quite differently to the way results are in the classical theory. The real numbers and the elements of any quantitative attribute form separate sets. As sets can consist either of abstractions or aggregates (Steckin, 1965), the representational theory of measurement does not require that the real numbers take an existence that can be empirically ascertained. All that is required is that they form an ordered set. Therefore, according to the representational theory of measurement, classical interpretations of instances of measurement are invalid.

Take the following example. It is found that a steel mass \( A \) weighs 12 kg and a brass mass \( B \) weighs 4kg. Classically, such results lead to the conclusion that \( A \) weighs three times as much \( B \). Representationally, the conclusion is invalid as it has violated the basic tenets of set theory as the behaviour of the elements within two different sets has become confused. A numerical conclusion of ‘being three times more than something else’ has been made of the elements of a non-numerical set. The argument, therefore, should be reinterpreted as follows. It has been discovered that the number in the set of the positive real numbers assigned to \( A \) on the kilogram ratio scale is 12 and the number assigned to \( B \) is 4. Therefore, the number assigned to \( A \) is three times the number assigned to \( B \). This way the measurements of \( A \) and \( B \) pertain to the numerical set of the real numbers and not to the ERS sets of \( A \) and \( B \). This is how the numerical results of measurement are presented by the representationalists.

**1.11 Problems and criticisms of the representational theory of measurement**

Such representational conclusions add considerable complexity to the interpretation of measurements and they argue that classical interpretations have no literal meaning (Michell, 1990). A representational conclusion of the relation between \( A \) and \( B \) would be something like this: ‘The concatenation of \( B \) with other brass masses of identical weight to \( B, C \) and \( D \) results in an object with the same weight as \( A \).’ While true, this conclusion is obvious in the classical theory as the numerical ratio instantiated by \( A \) and \( B \) literally tells us that \( A \) weighs three times as much as \( B \). The representational theory lacks this clarity and so has a problem with the meaning of numerical measurements. The representationalist Narens (1981b, p.263) admitted that this is a serious problem:
I think the description... of measurement structures in terms of their automorphisms has been fruitful and provided insights into the possible range of measurement structures. However, there are still problems, and from my view, the most important of these revolve around the concept of "representation" – at this time we just do not have a very clear idea as to what "representations" should be or how to select the "correct" one or set of ones.

It must be stated that the representational theory of measurement as it now stands is a logically coherent argument. But as Michell (1990, 1995) has argued, the representationalists cannot argue of the location of numbers. The concept of homomorphism as employed by the representational theory of measurement hits the following empirical problem. Let us select two objects - a piece of steel reinforcing bar and a piece of steel railway line. It is quite easy to empirically demonstrate the homomorphisms between the empirical relational structures of both objects. For example, take the objects’ lengths. If they are found via concatenation to be identical in length, the homomorphism between the length ERS’s of both objects takes the form of an isomorphism. That is, there is a function $\alpha$ mapping the elements of the bar length ERS set $R = \langle R, \geq, P_0, P_1, \ldots, P_n \rangle$ into the length elements of the railway line length ERS set $T = \langle T, \geq, U_0, U_1, \ldots, U_n \rangle$ such that $P(x_1, \ldots, x_m) \leftrightarrow U(t(\alpha v_1, \ldots, \alpha v_n))$, $\alpha$ being a real valued function of 1. A homomorphism between their masses would also exist. If it was found that two steel reinforcing bars were needed in one cup of a pan balance to balance the mass of the railway line in the other cup, exactly the same set notation could be used to describe the homomorphism but $\alpha$ would have a real value of 2.

Empirical evidence for these homomorphisms can be found as both exist as concrete entities in the spatiotemporal realm. Thus their properties and the relations (such as homomorphisms) that they enter into are either directly or indirectly observable. Now in order for the representational theory of measurement to provide empirical evidence for the homomorphism between empirical relational structures and the real numbers, empirical evidence has to be found that the latter exist as spatiotemporally located objects. This is the only way the representational theory of measurement can be held true (Michell, 1997a). But the representationalists do not argue that the real numbers exist as objects but as Platonically realistic set theoretical entities that cannot be empirically detected. How can there be, then, an homomorphism relation between empirical relational structures and the real numbers when the latter is beyond scientific observation? How can empirical support be provided for the type of homomorphism
utilised by the representationalists if one of the two entities that comprise the homomorphism is beyond detection by empirical science?

How do the representationalists respond to questions such as these? Obviously they recognise that numbers do not exist as objects. Surprisingly, an explanation similar to the classical measurement view of number will be forthcoming. Luce (1996, p.79), himself one of the most important representationalists, stated:

> Although many of us today, e.g. FM - 1, 2, 3, may appear to treat numerical systems platonically - as an abstract concept given a priori - I think that most of us recognise, as Michell (1990) has been at pains to point out, that the additive rational numbers really arise as an abstract formalisation of the structure exhibited by many physical attributes.

What Luce appears to be arguing here is that the real numbers (or the rational numbers at least) form sets (the “abstract formalisation”) as an artefact of their being Euclidean ratios. As only additive structures instantiate ordered classes of ratios as per the concept of the Archimedean ordered mathematical group (Luce, 1987), their a priori inclusion as ordered elements within a set actually follows from the additive automorphic structure of quantities. Thus the set of the real numbers appears only to be an abstraction upon the real numbers and is not in itself a necessary and sufficient condition for the existence of the real numbers. So it appears that the representationalists will admit that the natural world is complex enough to support the complexity of the real numbers. If, however, they incorporated this admission into their work on measurement, they would soon see the representational theory of measurement as redundant.

There have been other criticisms made of the representational theory of measurement. A largely misguided one by the social constructivist Schwager (1991) stated that “…writings in RMT sometimes interpret a data structure incorrectly” (p.625). The basis for this comment came from the use of mass and pan balances in the FM series as an illustration of representational concepts. Schwager argues that pan balances confuse mass for weight and hence so does the representational theory of measurement. This Schwager argues renders the theory “…unable to separate theoretically distinct concepts” (p.625) and thus its application to psychology has to be “…supplemented, at least, by construct-and-criterion-related evidence of validity” (p.265).

This argument is incorrect on two accounts. Firstly, the psychometric concept of validity\^1\^ is made redundant by measurement theory as only the latter has the capacity to identify additive structure in psychological attributes. It would be prudent, however, for

\^1\^ “A test is said to be valid if it measures what it purports to measure” (Kline, 1988,p.34)
any psychometric investigator to pay empirical attention to validity but in no way does
the application of measurement theory to psychology require the concept of validity,
either empirically or theoretically. Secondly, weight is a scalar quantity as it is the
product of mass and acceleration due to gravity. The representational theory of
measurement can easily explain this through multiplicative conjoint measurement.
Krantz et al (1971) demonstrate that physical measurement is the products of powers of
dimensions; in the weight case it is \( W = [M][S][T]^{-1} \)\(^2 \) where M is mass, T is time and S
is displacement. That the representational theory of measurement cannot “separate
theoretically distinct concepts” by its pedagogical use of mass is simply untrue.

The psychometrician Cliff (1992), whilst extolling the virtues of the representational
theory of measurement, argued that the theory has had little impact because: a/ the
mathematics is too hard for most psychologists to understand; b/ the axioms are
intolerant of error and c/ there is little in the way of successful examples. Both Narens &
Luce (1993) and Michell (1999) responded to Cliff (1992) and found the problem of
critical. The psychometrician Ramsay (1975) reviewed Foundations of Measurement Vol I (Krantz et al, 1971) in the flagship journal
of psychometrics Psychometrika. In it Ramsay also mentioned the problem and the
neglect of Krantz et al to include a chapter on how their work could extend to
psychometric problems. Ramsay (1991) reviewed the following volumes and basically
reiterated his concerns of 16 years before. Ramsay concluded that “…the Foundations of
Measurement volumes are simply a triumph” (p.358) and argued that as a consequence of
their publication, psychometrics should not call its practices measurement, especially in
the area of mental testing. This conclusion is overextended and may not be applicable to
the Rasch Item Response Theory (IRT) model (Rasch, 1960) which is used in the area of
ability assessment.

As it exists, the representational theory of measurement has had little impact upon the
natural sciences. There the classical theory of measurement still forcefully holds. In its
pure form, the representational theory of measurement has also had little impact upon the
behavioural sciences. But in a mutated, malignant form, based upon pre Krantz et al
(1971) representational measurement theory, it has had a pervasive influence over
quantitative practices in psychology.
2.1 Stevens’s (1946) operational definition of measurement

The Harvard psychologist Stanley Smith Stevens (1946) succinctly delivered a concept of measurement held as definitive within psychology yet unknown in any other branch of empirical science:

Measurement is, in the broadest sense, defined as the assignment of numerals to objects and events according to rule (p. 677).

It was not the case that Stevens was unaware of the classical and representational theories of measurement. Rather, he incorrectly thought that the subject matter of the behavioural sciences necessarily invalidated those theories of measurement:

Among those whose interests centre on variables that are not reducible to meter readings, however, the concern with measurement stays acute. How, for example, shall we measure subjective value (what the economist calls utility), or perceived brightness, or the seriousness of crimes? Those are some of the substantive problems that have forced a revision in our approach to measurement. They have entailed a loosening of the restricted view bequeathed to us by the tradition of Helmholtz and Campbell - the view that the axioms of additivity must govern what we call measurement (1968, p.854).

Stevens’s definition of measurement is essentially a mutation of Campbellian representational measurement theory. It is operationist as it is not the real numbers that are assigned to certain structures in objects and events in such a way that the structure is reflected in the class of assigned numbers. Rather it is the numerals, the symbols used to designate the numbers, which are assigned directly to objects or events (without any regard for structure) by the human act of performing operations on those objects or events. These operations Stevens termed ‘rules’ as he thought such operations on objects or events could be codified to a certain extent. Certainly, there appears in representational measurement to be an adherence to rules and hence Stevens’s definition of measurement may appear to be superficially representational. But it is not.

Here is not the place to review extensively the doctrine of operationalism. Hardcastle (1995), Moyer (1991a & b), Michell (1999), Rogers (1989), Koch, (1992) and Green (1992) have already done so. A brief overview, however, is necessary.

According to Moyer (1991a & b), the Harvard Nobel laureate for physics P.W Bridgman thought that the reason for the revolutionary development of Einstein’s theory
of general relativity was that Newton had relied far too much on the metaphysical presuppositions of the basic quantities of length, mass and time. Consequently, Bridgman reasoned that to stop another such sudden and pervasive change in physics, all the metaphysical content of this discipline had to be removed. The metaphysical and abstract had to be replaced by something observable and concrete so that such ‘mistakes’ as Newtonian physics could forever be avoided. Given that the corpus of physics consists entirely of quantitative attributes, and that physical measurement is concerned with the behaviour of these attributes, the doctrine of operationism had to extend to include physical measurement. The traditional concepts used in physical measurement, such as ‘ratio’, ‘magnitude’, ‘pure number’ and ‘unit’ were judged by Bridgman to be peculiar to Newtonian physics and hence were too metaphysical. The human act of performing measurements, however, was an easily observed behaviour firmly located in time and space. It had a tangible existence and could easily be defined and codified. Hence Bridgman wrote of physical measurement in his influential 1927 book The Logic of Modern Physics (cited in Moyer, 1991a, p.237) that:

In general, we mean by any concept nothing more than a set of operations; the concept is synonymous with the corresponding set of operations. If the concept is physical, as of length, the operations are actual physical operations, namely, those by which length is measured; or if the concept is mental, as of mathematical continuity, the operations are mental operations, namely those by which we determine whether a given aggregate of magnitudes is continuous (original emphasis).

Within physics, the concept had a relatively short life span. As was demonstrated earlier, physics still advances the classical theory of measurement as true. The cause of operationalism’s death was relatively simple. Consider any physical quantity \( Q \). Let there be physicist \( A \) with a particular measurement operation \( M \) for use on \( Q \). In order for measurement to take place, \( A \) must enter into a relation with \( Q \). This relation \( A_{MQ} \) must exist if \( A \) is observing \( Q \). What physics realised is that operationism confuses this relation \( A_{MQ} \) with \( Q \) and so denied that \( Q \) has an existence independent of \( A \). In arguing that \( A_{MQ} \) is synonymous with \( Q \), operationism had made the mistake of confusing the relation between two terms (\( A \) and \( Q \)) for a property of one of them (\( Q \)) (Michell, 1999). This does not mean that \( A_{MQ} \) is a fiction. It indeed exists whenever measurement occurs. But as the identification of \( A_{MQ} \) with \( Q \) logically prevents the behaviours of \( Q \) from being interpreted realistically, physicists discontinued believing operationism to be true.
2.2 The presence of the operational theory of measurement in the behavioural sciences.

Unfortunately for psychology, Stevens did not realise the problem of operationalism. Stevens (1935b, p.323) boldly stated in unambiguous terms that:

The revolution that will put an end to the possibility of revolutions is the one that defines a straightforward procedure for the definition and validation of concepts, and which applies the procedure rigorously in a scrutiny of all fundamental concepts in psychology. Such a procedure is the one which tests the meaning of concepts by appealing to the concrete operations by which the concept is determined. We may call it operationism. It insures us against hazy, ambiguous and contradictory notions and provides the rigor of definition which silences useless controversy.

It is very difficult to overestimate the influence that S.S. Stevens has had over quantitative and general psychology during the past 50 years. Michell (1997b) made an inquiry into the status Stevens’s writings hold today; and conducted a survey of 44 monographs pertaining to social or psychological measurement within the library of a major European university. Of these monographs, 39 declared measurement as some version of Stevens’ assignment of numeral to objects and events according to rule; often using terms that have become synonymous with numeral such as score, symbol and numerical value. Not one of the monographs, even those 5 which did not champion Stevens’s definition or some version of it, made reference to the classical theory of measurement, viz., the discovery and estimation of the real number instantiated by the relationship between a magnitude of a given quantity and a unit magnitude of the said quantity. Michell (1997b, p.360) concluded that his observations “… confirm that psychology, as a discipline, has its own definition of measurement, a definition quite unlike the traditional concept used in the physical sciences.”

In an attempt to replicate Michell’s (1997b) findings, the author conducted a similar survey in the libraries of the University of Sydney and the University of Western Sydney. Fifty monographs were surveyed, ranging from statistics-for-psychology texts to psychometric texts to research-methods-for-psychology texts12. The criterion for a monograph’s inclusion in the survey was that the monograph purported to discuss some kind of psychological measurement. The author surveyed the texts to determine how many of them cited: a/ Stevens’s theory of measurement (referenced or not); b/ Stevens’s theory of scale types (referenced or not); c/ the classical theory of measurement; d/ the representational theory of measurement or e/ no theory of measurement.

---

12 All monographs used in this survey appear in Appendix 15.
Nearly half (24) of all the texts, in some form, gave the assignment of numerals to objects and events according to rule as the definition of measurement. Of these, only 9 correctly referenced their definition to Stevens. Thirty-one mentioned his theory of scale types as the ‘four-kinds-of-measurement’, with only 9 correctly referencing Stevens. Only two gave the classical definition of measurement and they were both Michell’s (1990, 1999) texts. Six gave some version of the representational theory of measurement while fully 10 did not explicitly mention any form of measurement at all! Thus from the results of this survey, Michell’s (1997b) conclusion that psychology has its own definition of measurement, viz., Stevens’s theory, was strongly supported.

2.3 Stevens’s (1951) theory of scale types

Stevens was deeply impressed with how powerful the discipline of mathematics had been when applied to the sciences of physics and chemistry. He wrote: “The stature of a science is commonly measured by the degree to which it makes use of mathematics... when description gives way to measurement, calculation replaces debate” (1951,p.1) and that: “... we are awed by the prodigious power of mathematics to see what is beyond our own vision. In this mathematical puissance, the ancients detected a mystical splendor - a proof that number rules the universe” (p.2). Stevens believed that the discipline of mathematics was “... deliberately rigged to make the game13 isomorphic with common worldly experience, so that ten beans put with ten other beans to make a pile is mirrored in the symbolics: 10 + 10 = 20” (1951,p.2). Stevens (1951,p.1) attempted to marry this formalism with the representational concept of empirical relational structure; and the product was his necessary and sufficient conditions for measurement:

Measurement is possible in the first place only because there is a kind of isomorphism between (1) the empirical relations among objects and events and (2) the properties of the formal game in which numerals are the pawns and operators the moves. When this correspondence is close and tight, we find ourselves able to discover truths about matters of fact by examining the model itself.

To Stevens, mathematics provided both a way of stifling debate or “useless controversy” over psychological measurement and a method by which psychology could be placed on a sure scientific footing. This method was to use mathematics to serve “... as a model to represent empirical operations” (1951, p.2). Of these empirical operations there were 4 basic kinds: the determination of equality, of greater or less, of equality of

---

13 Stevens (1950) thought of mathematics as nothing more than a game played with symbols; an “...instance of man’s creating his own gods.... like chess, and men not only play the game, they also make the rules”
intervals or differences and equality of ratios. The mathematical models of the basic empirical operations were, respectively, his famous nominal, ordinal, interval and ratio scale types.

Stevens first made mention of his theory of scale types in Table 1 of his 1946 paper in the journal *Science*, directly underneath his first definition of his theory of measurement. There he made it quite clear that scales were only human operations performed on natural attributes; although he did make a small, token concession to the role natural structures play in measurement:

The type of scale achieved depends upon the character of the basic empirical operations performed. These operations are limited ordinarily by the nature of the thing being scaled and by our choice of procedures, but, once selected, the operations determine that there will eventuate one or another of the scales listed in Table 1 (1946, pp. 677-8).

The rest of the paper is devoted to both the explanation of what he meant by his scales and to certain prescriptions regarding their use. He also grafted onto his arguments a means to solve the perennial confusion surrounding the role of statistics in psychology. This also became known as his theory of permissible statistics (Michell, 1986, 1990, 1999).

2.4 The Nominal scale

The conceptually simplest of Stevens’s scales was the *nominal* scale. In this scale, Stevens argued, numerals have their most unrestricted assignment and are used for no other purpose than to label certain phenomena. For example, the various nationalities of a class of people could be labelled ‘1’ for Australian, ‘2’ for American, ‘3’ for British, “750” for New Zealander and so on. Basically, this was Stevens’s way of attempting to force the essentially qualitative psychological attributes to square with his unashamed Pythagoreanism. Stevens was aware of the potential criticism this assault of his could generate so he related it back to his operational definition of measurement: “... the use of numerals as names for classes is an example of the assignment of numerals according to rule. The rule is: Do not assign the same numeral to different classes or different numerals to the same class. Beyond that, anything goes with the nominal scale” (1946, p. 679). Thus he fallaciously countered that this mere numerical coding of qualitative attributes was actually a form of measurement. This rule he refers to, the only explicit rule he ever gave for the assignment of numerals, defines the admissible scale transformation of the scale type as the class of all one-to-one transformations (Michell, 1986). Stevens argued that this scale remains invariant under the permutation
mathematical group structure where \( x' = fx \) and \( fx \) means any one-one substitution\(^{14}\). This means that in the previous example, we could label Australians “5” and the British “30”, but we could not give either label to both. Of course, there are an infinite number of possible one-one substitutions that could be used. The only permissible statistic was the mode as only it would remain invariant under such transformations, although later Stevens (1968) was to add the Chi-Square and Fischer’s exact test to his prescriptions for the nominal scale.

2.5 The Ordinal scale

The next of Stevens’s scales was the ordinal scale. An ordinal scale is used where it is thought that the entities of a given class stand in some monotonic relation to one another. For example, a class of marked lab reports may typically be assigned the letters A, B, C, D or E with A denoting the reports of the highest quality, B the next highest and so on to E, the reports of the poorest quality. Such an assignment produces a simple order, that is, it is transitive, asymmetric and connected; and reflects nothing more than an ordering of different levels of perhaps a qualitative attribute (in this case, writing ability). The assignment of letters does not accord with Stevens definition of measurement but their substitution by the numerals 1, 2, 3, 4 and 5 would. Thus the ordinal scale is another forcing by Stevens of attributes that are perhaps qualitative into a ‘quantitative’ state. Stevens argued that the structure of this scale was of the mathematical isotonic group where \( x' = fx \) and the \( fx \) meant any monotonically increasing function.

Interestingly, Stevens’s writings on the ordinal scale betrayed a critical view of the status of psychometric tests. He argued:

\[
\text{As a matter of fact, most of the scales used widely and effectively by psychologists are ordinal scales. In the strictest propriety the ordinary statistics involving means and standard deviations ought not to be used with these scales, for these statistics imply a knowledge of something more than the relative rank order of data (1946,p.679).}
\]

Stevens prescribed that only the calculation of the median and percentiles were allowable with ordinal scales as “...means and standard deviations computed on an ordinal scale are in error to the extent that successive intervals on an ordinal scale are unequal in size (1946, p.679). Thus only medians and percentiles would remain invariant under admissible scale transformations, which are for the ordinal scale the class of monotonic increasing functions (Michell, 1986). In the lab report example, the following

\(^{14}\) Stevens was wrong in thinking that the transformations of the nominal scale formed mathematical groups. Narens (1981,a&b) found no empirical relational structure capable of supporting the nominal
numerals could be assigned, respectively, -50.7, 2, 13.33, 584 and 11000, an assignment also one of an infinite number. Such an assignment is a simple order but unlike the 1, 2, 3, 4, 5 assignment, the illusion of equal distance between the numerals is shattered.

2.6 The Interval scale

With his *interval* scale, Stevens incorrectly stated that "...we come to a form that is 'quantitative' in the ordinary sense of the word" (1946,p.679). He mistakenly thought that the operation of assigning numerals so that each numeral appeared equally spaced from its immediate neighbours necessarily formed a finitely bounded standard sequence of measurement. These scales have as their mark apparently equal intervals and an arbitrarily set 'zero' point. The best examples of interval scales are the Celsius and Fahrenheit temperature scales and Stevens used them illustratively in his writings without fail. Focussing on the Celsius scale, the zero point is set as the freezing point of water at sea level and each degree Centigrade indicates by convention the amount of heat energy required to expand a volume of any gas by one one-thousandth of a litre (Brescia, Arents, Meislich & Turk, 1975).

Stevens (1946, p.679) argued that "Most psychological measurement aspires to create interval scales, and sometimes it succeeds." Stevens may have been thinking of Likert's (1932) theory of summated ratings as evidence of this success; given the enormous use of Likert's rating scales within psychometrics. Having said this, there is no doubt that Stevens thought that there were very few interval scales in psychology. Most of those, he thought, were psychologists attempting to move beyond the ordinal scale, such as in intelligence testing.

The permissible transformations of the interval scale are the class of positive linear transformations (Michell, 1986), also known as affine transformations (Krantz et al,1971). In Stevens's (1946, Table 1) argument, such transformations formed general linear mathematical groups of the form $x' = ax + b$. Such transformations exist between the Celsius and Fahrenheit temperature scales, being $^\circ F = 1.8^\circ C + 32$ and $^\circ C = (^\circ F - 32) \times 1.8^{-1}$. Stevens, thinking that an interval scale had the properties of a finitely bounded standard sequence expounded: "Almost all the usual statistical procedures are applicable here, unless they are the kinds that imply a knowledge of a 'true' zero point" (1946, p.679). These included means, standard deviations and both the rank-order and product-moment correlations. Later, he (Stevens, 1968) was to add the Student's $t$-test and

scale as measurement, admitting that it was just a numerical coding procedure.
Fisher's Analysis of Variance procedures. For Stevens, operationalising a psychological ‘construct’ at the interval level rendered it quantitative.

2.7 The Ratio scale

Finally, Stevens argued of the existence of the ratio scale: the highest order scale within his theory. Unable to turn to any psychological examples, Stevens stated correctly that mass, length, time, plane angle and electric charge were ratio scalable. Stevens, however, found it difficult to accept that temperature could be measured using the ratio scale of the Kelvin, mockingly referring to it a “… the so-called Absolute Scale” (1946, p.679)\textsuperscript{15}. This was perhaps due to the problem of identifying which ‘operational’ definition of temperature, the Celsius, Fahrenheit or Kelvin, was the most ‘meaningful’ to him. The important difference separating the ratio scale from the interval is that in the former it is assumed that a “true” zero point has been ascertained. Identifying this fixed zero point of the scale, then determining the equality of intervals on the rest of the scale was the construction of a ratio scale in the first instance (Stevens, 1951). This done the equality of ratios could be determined by taking the ordered assigned numerals \(a, b, c, d, e, f\) and \(g\) of the scale and showing, given the equality of intervals, that the ratio of interval \((a, b)\) to interval \((c, d)\) was equal to that of \((d, e)\) to \((e, f)\). Other scales could then be constructed through the class of positive similarities transformations pertinent to the ratio scale (Michell, 1986). In Stevens’s (1946) parlance, such transformations formed mathematical similarities groups of the form \(x' = ax\). In other words, multiplication by any positive, real – valued constant produces another ratio scale. For example, if we are using inches from the Imperial scale to measure the length of any object, we can transform the result into millimetres from the SI scale by multiplying by 25.4. All the statistical procedures open to the interval scale could be used with the ratio scale. Moreover, logarithmic transformations were also possible and Stevens (1968) later added the calculation of geometric and harmonic means.

2.8 Criticism of Stevens’s theories of measurement and scale types

Stevens’s theory of scale types fails empirically even in the most elementary of situations. For example, the author has on his desk a complete collection of Encyclopaedia Britannica’s Great Books series. The series is comprised of 54 volumes

\textsuperscript{15} The Kelvin Scale is the SI unit of measurement for temperature. Stevens referred to it as Absolute as it has as its zero point the theoretically lowest possible temperature in the universe of -273.15°C (Brescia, et al,1975). One degree Kelvin is equal to one degree Centigrade. For example, the background microwave radiation of the universe has a temperature of approximately 3°K or -270.15°C. Stevens (1968) eventually accepted that temperature was indeed ratio scalable.
and all have been assigned a numeral ranging from 1 to 54, in part, to reflect a chronological ordering of the greatest ideas in the history of Western thought. It is a perfect example of an assignment of numerals according to rule, but as Ellis (1966) and Kline (1998) point out in similar examples, what actually has been measured? This is not a trivial question as it demonstrates Stevens’s failure to think of a conceptual equivalent of the attribute. The volumes are objects, each volume has an assigned numeral, the volumes are simply ordered, there is a fixed ‘zero’ point in that there are no volumes which precede the first and the assignment obliges Stevens’s permitted positive similarities transformations for the ratio scale. Therefore, it is a ratio scale, a scale of the highest repute, and so is on par with the ratio scales of the fundamental quantities of physics! Consequently, in Stevens’ view, it must be measuring something. What indeed is being measured? The first volume of Aristotle’s works has the numeral 8 and the volume containing the selected works of Ptolemy, Copernicus and Kepler has the numeral 16. If we oblige Stevens’s theory and focus upon the scale alone, this latter volume must have twice as much of something as Aristotle’s one. Is it that the works of Ptolemy et al are twice as important? Are the ideas twice as difficult? Did Aristotle write half as much? Did Aristotle have only half the original ideas? Did Ptolemy et al take twice as long to write their works? Of course, these questions are pure nonsense, yet they illustrate the problem experienced if we follow Stevens in thinking that only the scale is important and not any of the underlying attributes within the objects themselves.

Here is where Stevens’s theory fails to derive an operational equivalent to the concept of attribute. It is obvious that the volumes form a 54 membered aggregate and the assignment of numerals to them directly reflects this. As such the volumes instantiate the natural numbers from 1 to 54 and it is ridiculous to state that an aggregate is a ratio scalable continuous attribute. However, as the 19th Century German mathematician Frege (1884) argued, this aggregate can be sliced an almost infinite number of ways, so the assignment is not unique and cannot tell us everything about the volumes unless one specifies the property of interest. Therefore, as Stevens argues that there must be an isomorphism between the empirical operation and the scale type for measurement to have

---

16 Ellis brewed his own remedy to Stevens dictum: “Always Measurement is the assignment of numerals to things according to any determinative, non-degenerate rule.” (1966,p.41). Ellis meant by determinative that the same numerals are assigned to the same objects or events under the same conditions, provided that “...sufficient care is exercised.” (p.41). By degenerate he meant that the rule could assign different numerals to different things or the same thing under different conditions. Ellis does nothing here except add another prescription onto Stevens’ definition, engages in some wishful thinking and fails to escape the clutches of operationism.
occurred, this isomorphism cannot only pertain to the volumes themselves unless we have specified the property 'being a volume' as the one we are interested in measuring. Here we must introduce the metaphysical concept of 'property' before we begin to assign numerals by whatever rule, thus contradicting Stevens.

To counter this, Stevens could have done two things. Firstly, he may have argued that questions about properties are items of 'useless controversy' and we should just be contented with our ratio scale. Or he could have argued that we must operationalise what we mean by property but this implies that there actually exists, in the first instance, this metaphysical concept of property upon which such operations are to be based. By Frege's (1884) arguments objects possess more than one property, so if we adhere to Stevens's doctrine of only looking at the scale once we have devised one, our understanding of the object is very poor unless we identify and then scale all the properties contained in the said object. As Stevens does not allow such things as properties, and we cannot operationalise them without actually admitting that they exist, we cannot execute this very task. It is little wonder then that psychologists admit the existence of metaphysical properties in human behaviour by first identifying what properties they are interested in before beginning their investigations, then operationalising such properties, even though Stevens outlaws this completely.

It can be argued, however, that the above argument is misdirected as it involves analysing Stevens's (1946) theory with the concepts of property and attribute associated with the classical theory of measurement. The classical theory is no longer the *sine qua non* of measurement in the philosophy of science (Michell, 1999) and therefore it can be argued that Stevens's theory is being criticised from the viewpoint of an outdated theory of measurement. It can also be added that Stevens's theory had its origin in the theory of measurement that superseded the classical — the representational — and hence it too supersedes the classical. Such reasoning, however, is incorrect and not because it works from the false premise of the redundancy of the classical theory. Stevens's concept of the measurement rule and his particular argument concerning the absolute importance of the scale encounters the same problem if analysed by the representational theory as it does with the classical. The major difference is in the terminology employed.

Take the representational concept of the empirical relational structure. Stevens rightly argued that it is a necessary condition for measurement. The representationalists (Krantz et al., 1971; Luce, 1986, 1987; Narens, 1981a & b), however, firmly argue that empirical relational structures have an existence independent of human observation, as outlined in
the previous chapter. Stevens does not agree. He argues that empirical relational structures are natural facts and should be ignored in favour of their operationally derived mathematical models or scales (Stevens, 1951). Krantz et al (1971) firmly state, and indeed demonstrate, that a scale is simply the homomorphism, a relation, between the empirical relational structure and the class of the real numbers. As a homomorphism is a relation between two terms there must exist independently of the relation these very two terms. Otherwise the representational theory is illogical. Stevens, however, claims that the homomorphism into the real numbers, or scale, caused by the empirical relational structure is indeed the empirical relational structure. So according to the representationalist view, Stevens mistakes his rule – made ‘scale’ in the Great Books example for the empirical relational structure of the Great Books themselves. The representationalists, however, may not agree with an aggregate of book volumes being an empirical relational structure in the same way that length is. It is more likely that they would dismiss Stevens’s theory out of hand, and indeed they do (Krantz, et al, 1971; Luce, 1997).

The problem identified in the Great Books example has been understood for some time, but ignored. The Canadian measurement theorist Rozeboom (1966), a persistent critic of Stevens, has savagely attacked both Stevens’s concept of the admissible scale transformation and Stevens’s dismissal of the role of natural structures in measurement. Rozeboom (1966, Def. 15) stated that the only way the ‘ratio scale’ of the Great Books example could hold would be to decree that the scale is both absolute and exhaustive. What Rozeboom meant by those terms is best clarified by the use of set theory.

If we have an empirical relational structure $X =< X, >, R_1, ... R_n >$ or what Rozeboom terms a natural variable, a real relational structure or scale $N = < R, \geq, S_1, ... S_n >$ is absolute iff the transformation of the primitive relations $R_1, ... R_n$ into the real relations $S_1, ... S_n$ is ‘significant’. The scale is exhaustive iff there are no other ‘significant’ relations in $R_1, ... R_n$ whose image relations are not those entailed by the image relations $S_1, ... S_n$ of $R_1, ... R_n$. Rozeboom states that this argument rests on the very problematic grounds of what is meant by the term ‘significant’. All Rozeboom could do in relation to this problem was to conclude:

I am sceptical that there exists any useful dichotomous distinction between properties which are ‘significant’ and those which are not; instead, I suspect that each property or relation which we are able to conceive of has its own particular degree of significance or
'meaningfulness' imparted by its nomological implications and/or the personal satisfactions we receive from it (1966, p. 190).

In other words, Rozeboom argues that because objects and events usually possess more than one property, no single scale in Stevens's theory of scale types is either exhaustive or absolute of the natural structure it purports to reveal. Moreover, Rozeboom suggests that significance is a relativistic concept as it is defined by the investigator and is not found in the features of the natural structure of interest to the investigator.

What happens, however, if we take the converse argument and state that a Stevens scale is both absolute and exhaustive? Rozeboom argued that the following occurs. Take again the Great Books example. Let it be that the numerical assignment is made such that a nominal scale arises in the class of the real numbers. That is, the numeral '8' represents the property 'the first volume of Aristotle's ideas' and the numeral '16' represents the property 'the ideas of Ptolemy, Copernicus and Kepler'. The numerical assignment, however, enables the numerical relation of the ratio form $16 = 2 \times 8$ to exist. If such a real relational structure exists in the class of the real numbers, Rozeboom argues, then there must be an empirical relational structure capable of supporting this real relational structure. Rozeboom is a representationalist and the property defined across the Great Books would be 'the class of all important ideas in Western thinking'. So according to Rozeboom, our initial use of a nominal scale was incorrect as we have discovered that is was a ratio scale. As ratio scales contain much more information about the empirical relational structure, why would anyone wish to use the nominal one? But Stevens, Rozeboom argues, through the concept of the admissible scale transformation, does not allow the use of the ratio scale as it is related to the initial nominal scale by an inadmissible transformation.

Rozeboom (1966) developed this point further. Rozeboom argues that the only way Stevens could argue that the Great Books 'ratio scale' was indeed a ratio scale was through the execution of the admissible scale transformation of $x' = ax$. If the values 1 to 54 are taken of the original scale as constituting $x$ and if $a$ is taken as a real-valued constant of 3, then $x'$ is also a ratio scale consisting of the values 3 to 162. According to Stevens, since $x'$ is a ratio scale then $x$ must have been one in the first instance as the transformation was invariant. However, this could not be possible as we initially commenced with a nominal scale! Rozeboom (1966) identifies the exact cause of this problem with Stevens's theory. He states:
Observe to begin with that a class of admissible scale transformations is defined in terms of a scale \( \phi \) and its class \( Q \) of significantly interpretable num relations. Hence the admissible – transformation concept says nothing about what initial scale to adopt for a natural variable \( \alpha \) – it only says that once we have scaled \( \alpha \) as \( \phi \), then we are allowed to rescale only by transformations which preserve its type. But if the set of significant \( \alpha \) – value relations is represented by some set of num relations on any num – valued formal scale for \( \alpha \), so if \( \phi' \) and \( \phi \) are two alternative scales for \( \alpha \) related by an inadmissible transformation, a person who first chose to scale \( \alpha \) as \( \phi' \) would be prohibited by ST doctrine from subsequently replacing \( \phi' \) by scale \( \phi \) even while \( \phi' \) is proscribed for use by anyone who first scaled \( \alpha \) as \( \phi \) (1966,p.192, original emphasis).

In other words, Stevens’s deliberate ignorance of the role of natural structures play in measurement does not enable him to provide any convincing argument for the scaling of any natural attribute in the first instance. The argument that Rozeboom makes here is far from trivial. Consider the quantity temperature. It can be measured using either an interval (Celsius) or ratio (Kelvin) scale. Rozeboom argues that according to Stevens’s theory the two scales are related by an inadmissible transformation. A scientist who measures temperature using the interval scale Celsius measure \( (\phi') \) cannot by Stevens’ arguments replace the Celsius measure by the ratio scale Kelvin measure \( (\phi) \). It is possible, however, for another scientist to measure temperature on an interval scale \( (\phi') \) if that scientist commenced measurement with a ratio one \( (\phi) \), given the logarithmic transformation permitted for ratio scales (Stevens, 1968). This is perhaps why Stevens mocked the Kelvin scale of temperature as it highlighted the flaw in his concept of the admissible scale transformation. Within the confines of his theory, Stevens could not explain why temperature could be both interval and ratio scaled. The answer is of course because temperature is a quantity and thus forms an Archimedean ordered and homogeneous set of translations (Luce, 1987).

Rozeboom’s argument about the concept of admissible scale transformations is essentially a corollary to his arguments of scaling theory’s ignorance of natural structures. Rozeboom (1966, p.193) concluded that the only way Stevens’s theory of scale types could gain any scientific status was thorough the investigation of the natural attributes that seemingly give rise to the various scale types:

I urge, therefore, that both scaling theory and scaling practice stand to profit immensely more from a study of representation groups than from continued concern for type preserving transformation groups. For theory, determining the abstract structure common to
all scale types in a given interpretation group concomitantly reveals what structure a set of natural relations must have to be representable on any scale by a set of num relations in this group.

2.9 The theory of scale types representationalised – Louis Narens (1981a & b)

It must be stated, however, despite his arguments on psychological measurement per se, Stevens’s (1946) work on his theory of scale types actually lead to some important and highly original work within the representational theory of measurement. But the representationalists have been highly critical of Stevens’s work. Echoing Campbell and the Ferguson Committee, Krantz et al (1971) stated of Stevens’s sone scale:

In this experimental procedure, observers are asked to assign numbers to stimuli ‘in proportion to the sensations provoked’, and the resulting numbers are taken to be scale values....Stevens has not provided any argument showing that the procedure of magnitude estimation can be axiomatised so as to result in a ratio scale representation; he has neither described the empirical relational structure, the numerical relational structure, nor the axioms which permit the construction of a homomorphism (p.11).

Luce (1997a, p.395) even more bluntly stated:

...S.S. Stevens (1946, 1951, 1975) claimed that what counted was having an interval or ratio scale. Subsequent research has given meaning to this assertion, but given his attempts to invoke scale type ideas it is doubtful if he understood it himself... No measurement theorist I know accepts Stevens’ broad definition of measurement.... In our view, the only sensible meaning for ‘rule’ is empirically testable laws about the attribute”.

The subsequent research Luce mentions here was conducted by a colleague of those who authored the Foundations of Measurement series - the mathematical psychologist Louis Narens (1981a & b; 1985, 1996). Narens sought the possible empirical foundations of Stevens’s (1946) theory of scale types and was indeed highly successful. Narens (1981a & b) managed to strip Stevens’ theory of scale types of its operationalism and discovered that three of his four scale types could be supported by certain empirical relational structures. In so doing, Narens had uncovered something quite important. Stevens advanced only four scale types despite his theory of measurement allowing the advancement of an infinite number; as there were an infinite number of rules by which scale types could be invented. Remember that Stevens argued that nothing structural governed the construction of a scale. Narens uncovered that Stevens, through his theory of scale types, was actually trying to be a representationalist; hence admitting that natural structures were indeed very important.

Narens (1981b) introduced the concepts of homogeneity and uniqueness. Homogeneity states here that the automorphisms of a particular relational structure are as
homogeneous as points in Euclidean space, i.e. we have no reason to believe that any individual automorphism is different from all the other automorphisms of the same class (Narens & Luce, 1986). Uniqueness refers to the redundancy of the group of automorphisms (Narens & Luce, 1986).

An automorphism is an isomorphism between the elements of a set and themselves (Narens & Luce, 1986). For any set $X$, there exists a function $f$ which maps elements of $X$ into other elements of $X$ in such a way that a one-to-one correspondence is established, with such a mapping preserving the associative and distributive laws, provided that the elements in $X$ stand in a particular relation, R. Narens (1981 b, p.253) formally defined an automorphism thus: For a relational structure $X = \langle X, \geq, R_0, R_1, \ldots, R_n \rangle$, $\alpha$ is an automorphism iff $\alpha$ is a function mapping $X$ onto $X$ such that for $i = 0, 1, 2 \ldots$ and each of the elements $a_1, \ldots a_n$ in $X$: $R_i(a_1, \ldots a_n)$ iff $R_i(\alpha(a_1), \ldots \alpha(a_n))$.

If $Z = \langle Z, \geq, R_0, R_1, \ldots, R_n \rangle$ be a relational structure, with $\geq$ denoting a total ordering on $Z$ (that is, $Z$ is unbounded, dense and Dedekind complete), then let there be $A$, a non-empty class of automorphisms and a positive integer $n$. $A$ is then $n$-point homogeneous iff for each $a_1, \ldots a_n, b_1, \ldots b_n \in Z$ with $a_1 \succ a_2 \succ \ldots \succ a_n$ and $b_1 \succ b_2 \succ \ldots b_n$, there exists an automorphism $\alpha$ in $A$ such that $\alpha(a_i) = b_i$ for $i = 1, \ldots, n$. $A$ is then $n$-point unique iff for each $\alpha$ and $\beta$ in $A$, $\alpha$ and $\beta$ agree in $n$ distinct elements of $Z$, then $\alpha = \beta$.

Narens concludes that "$Z$ is said to satisfy $n$-point homogeneity if and only if the set of automorphisms of $Z$ satisfies $n$-point homogeneity; and $Z$ is said to satisfy $n$-point uniqueness if and only if the set of automorphisms of $Z$ satisfies $n$-point uniqueness" (p.254, original emphasis).

Michell (1990) argues that the importance of automorphisms is that they establish an isomorphism between the class of all possible numerical scales and the empirical relational system of interest. Narens (1981b) argues that $Z = \langle Z, \geq, R_0, R_1, \ldots, R_n \rangle$ is a Dedekind complete scalar structure iff all of the following are satisfied:

a/ $Z$ is a relational structure

b/ $\langle Z, \geq \rangle$ is unbounded, dense and continuous

---

17"Like homogenised milk, each part of space looks like each other part" (Narens and Luce, 1986, p.174).

18$N$-point uniqueness means: "...that if any two automorphisms that agree at $N$ nonequivalent points, then they are necessarily identical" (Luce, 1987, p.169).
c/ Z satisfies 1 point homogeneity and 1 point uniqueness

If Z is such a structure, Narens argues there exists \( N = \langle \mathbb{R}^+, \geq, S_0, S_1, \ldots S_n \rangle \) where \( \mathbb{R}^+ \) is the class of the positive real numbers and \( S_0, S_1, \ldots S_n \) being other relations on the positive real numbers then the following are true:

d/ There exists an isomorphic \( N \)-representation for \( Z \)

e/ The class of isomorphic \( N \) representations for \( Z \) forms a ratio scale. That is, \( r \varphi \)
is an isomorphic \( N \) representation for \( Z \) for each \( r \) in \( \mathbb{R}^+ \) and for each isomorphic \( N \)representation \( \varphi \) of \( Z \). Therefore, for all isomorphic \( N \) representations \( \varphi, \psi \) of \( Z \), there exists \( s \) in \( \mathbb{R}^+ \) such that \( \varphi = s \psi \).

Such a structure gives rise in the class of the real numbers to that which is known in
psychology as a ratio scale (Stevens, 1946). Thus a Dedekind complete ERS satisfies
Hölder’s (1901) axioms and is therefore additive and hence quantitative.

Narens argued that if it supposed \( Z = \langle Z, \geq, R_0, R_1, \ldots R_n \rangle \) is a linear structure (that is, satisfies a/ and b/ previously, but is instead 2 point homogeneous and 2 point unique) then \( N = \langle \mathbb{R}, \geq, S_0, S_1, \ldots S_n \rangle \) where \( \mathbb{R} \) is the class of all real numbers then the following are true:

f/ There exists an isomorphic \( N \)-representation for \( Z \)

g/ Each isomorphic \( N \) representation \( \varphi \) of \( Z \), \( r \varphi + s \) is an isomorphic \( N \)representation of \( Z \) for each \( r \) in \( \mathbb{R}^+ \) and \( s \) in \( \mathbb{R} \), and for all isomorphic \( N \) representations \( \varphi \) and \( \psi \) of \( Z \), there exists \( u \) in \( \mathbb{R}^+ \) and \( v \) in \( \mathbb{R} \) such that \( \varphi = u \psi + v \).

Such a structure gives rise to that which is known in psychology as an interval scale (Stevens, 1946).

The relational structure \( Z = \langle Z, \geq, R_0, R_1, \ldots R_n \rangle \) is a monotonic structure if and only if \( Z \)
and denumerable subsets of \( Z \) are dense; and that each subset of \( Z \) is without endpoints. \( Z \)
is then infinite point homogeneous iff for all denumerably dense subsets without endpoints \( A \)
and \( B \in Z \), then an automorphism \( \alpha \) exists of \( Z \) such that \( \alpha A = B \). \( Z \) is infinite point unique iff for all automorphisms \( \alpha, \beta \) of \( Z \), then \( \alpha = \beta \) for each denumerably dense subset without endpoints \( C \) if \( \alpha(C) = \beta(C) \). If \( Z \) is a monotonic structure, then there exists \( N = \langle \mathbb{R}, \geq, S_0, S_1, \ldots S_n \rangle \) and the following are all true:

h/ There exists an isomorphic \( N \)-representation for \( Z \)

47
i/ For each isomorphic N representation $\varphi$ of $\mathbb{Z}$ and each strictly monotonic function $F$ from $\mathbb{R}^+$ onto $\mathbb{R}^+$, $F(\varphi)$ is an isomorphic N-representation of $\mathbb{Z}$. For each $\varphi, \psi$ N representative isomorphisms of $\mathbb{Z}$, then there exists a strictly monotonic function $G$ from $\mathbb{R}^+$ onto $\mathbb{R}^+$ such that $\varphi = G(\psi)$ (Narens, 1981b).

Such a structure gives rise in the class of the positive real numbers that which is known as an *ordinal scale* (Stevens, 1946).

The culmination of Narens’ work is that the measurement scales used to assess quantitative attributes are clear emanations of the structures of quantitative attributes, although it must be remembered that ordinal scales *do not* indicate that an attribute is quantitative. An ordinal scale reflects that the elements of a non-empty class stand in some kind of unspecified order relation, and nothing more. Narens’ work is pertinent to the classical theory of measurement only in concern with the ratio scale. The classical theory’s dictum that measurement can only be achieved through the discovery and estimation of ratios necessarily excludes interval scales as measures (Michell, 1995). What the classical theory of measurement concludes from interval scales is that the differences between levels support ratios as per Hölder (1901, Part 2).

One outcome of Narens’s research, Michell (1990) argues, is that there can be no matching of homogeneity and uniqueness for any integer greater than 2 and less than infinity. For example, there cannot be an unbounded, dense and continuous quantity which is 3-point unique and 3-point homogeneous. Alper (1985), a former student of Luce’s, proves this in a series of lemmas which are essentially addenda to Narens (1981b) work. His work proves that no empirical relational structure exists whose elements are simply ordered and have automorphisms that are 2 – point homogeneous and 3 – point unique (Alper, 1985, Theorems 1 & 2). In general terms, there are no real relational structures extant in the class of the real numbers that are of the type $(m, m+1)$, $m \geq 2$ (Alper, 1985). This is why very few scale types have been found by the representationalists (Michell, 1990).

The great importance of Narens’s work was that it provided the first formal account of exactly which kinds of empirical structures give rise to the different scale types used in measurement. Moreover, this was achieved through the critical examination of the algebraic relations which various structures entered into with themselves. The structures had no need to be geometric like the fundamental physical quantities.
This is important to psychology and especially so to psychometrics. Both the fields of classical test theory (Lord & Novick, 1968) and item response theory (van der Linden & Hambleton, 1997) maintain that psychological attributes are measurable at least at the interval scale level. If this is indeed the case, the automorphism sets generated by such attributes could be assessed to see whether they are indeed 2-point homogeneous and 2-point unique. Yet it is unlikely that any psychometrician would contemplate this. No textbook in psychometrics mentions Narens’s (1981a & b) work at all; as evidenced by the survey mentioned at the beginning of this chapter.

If the assignment of numerals to objects and events according to rule cannot possibly yield interval scale measurements of psychological attributes in either the representational or classical senses of the term, what methodology exists by which genuine, interval scale measurement apparatus can be constructed? There is such a theory and methodology and it is known as axiomatic, simultaneous, additive conjoint measurement (Luce & Tukey, 1964; Krantz, et al, 1971). This rather new theory of measurement supersedes the work of Hölder (1901) in difference measurement; yet can yield results which satisfy Hölder’s axioms for line intervals. That is, it can discover empirically whether the intervals between levels of psychological attributes are isomorphic to the positive real numbers or not. Moreover, the attributes to which conjoint measurement is applied do not have to be geometric. The theory of conjoint measurement (Luce & Tukey, 1964) is the subject of the next chapter.
3.1 Fundamental Measurement

The physicist and measurement theorist N.R. Campbell (1921, 1957) argued that some basic quantities in physics were capable of sustaining a process of addition similar to that displayed by the real numbers. This process he called physical addition. Empirical demonstration of physical addition was conducted by the operation of concatenation. Concatenation simply means bringing together or combining of magnitudes of an extensive continuous quantity of a given kind. Campbell gave the following example of physical addition in the measurement of weight:

We state that the weights of two bodies $A$ and $B$ are “equal” when, is $A$ is placed in one pan of the balance and $B$ in the other, the final position of the balance is unchanged. We say that the body $C$ is “added to” the body $A$, when $A$ and $C$ are placed in the same pan of the balance; and that it is “subtracted from” the body composed of $A$ and $C$ in the same pan by removing $C$ from the pan. When we have thus defined “equal” and “added to” in the use of the pan balance, we can state, corresponding to arithmetical propositions which involve addition and equality, propositions about what will happen to the balance when we place bodies in the pan (1957, p.279).

Campbell called physical attributes capable of physical addition fundamental magnitudes as their measurement does not require the prior measurement of any other physical quantity. Weight (and mass), length, time, plane angle, volume, area, electric charge, electrical resistance and capacity and magnetic flux Campbell thought to be the fundamental magnitudes “…of any importance” (p.347).

An example of the measurement of a fundamental quantity is as follows. Mass is a fundamental quantity in that it readily demonstrates its additive structure in the behaviours of the natural structures that possess it. Hence mass can be identified as being additive via the operation of concatenation. If iron is taken as a natural structure possessing mass and a basic pan balance as the concatenation apparatus, a portion of this iron, $x$, can be taken and placed in one of the pans of the balance$^{19}$. This can be the tentative unit magnitude of mass. Another portion of iron can be fashioned and placed in the other pan so that the pans of the balance are level. This mass of iron can be designated $x$, and the level of the pans indicates $x \sim x$. Both $x$ and $x_1$ are concatenated

\(^{19}\) Strictly speaking the attribute being described here is weight, not mass. The weight of an object is the product of its mass and its acceleration (Aitchison, 1970). Acceleration in the example of the pan balance is acceleration due to gravity; this being approximately 9.8 m/s squared. The above example assumes for ease of description that mass and weight are equivalent attributes.
by placing them in the one pan and another portion of iron $x_2$ is fashioned and placed in
the other pan so that $x_2 \sim x \circ x$, by both pans being level. Another iron portion, $x_3$ could
be fashioned and placed in the pan balance so that $x_3 \sim x_2 \circ x$ resulted. Hence we have
arrived at a standard sequence for mass based on $x$. Of course, another such sequence
based on a portion of iron, $y$, differing to $x$ could be developed; both related by a positive
similarities transformation $y = \alpha x$ (Michell, 1986). For example, $x$ could have a real value
of unity and $y$ could have a real value of 3. An infinite number of standard sequences
could be constructed for mass given that it has demonstrated additivity via concatenation.
Hence it is infinitely symmetric given that its translations form 1-point homogeneous and
Archimedean ordered mathematical groups (Luce, 1987; Luce et al, 1990).

Fundamental measurement, however, has so far failed to be applicable to psychology.
No-one has discovered a suitable method by which magnitudes of emotions, intellectual
capabilities or personality can be concatenated, and attempts to do so have always been
in vain (see Krantz, Suppes, Luce & Tversky, 1971).

3.2 Derived Measurement

Campbell realised that the fundamental magnitudes far from exhausted the list of
quantitative physical attributes. Campbell observed that the greater majority of physical
systems existed in multiplicative relationships with the fundamental magnitudes and in
terms of importance played "...a part in science no less essential than fundamental
magnitudes" (p.336). Not capable of the operation of physical addition, these systems
depended completely on the prior measurement of fundamental magnitudes and hence
were derivations of them. Thus Campbell termed these systems derived magnitudes:

Such magnitudes, measured by the constants of numerical laws, are termed Derived
Magnitudes; for the process of their measurement, requiring the establishment of a
numerical law which requires again the previous establishment of some fundamental process
of measurement, depends entirely on the measurement of the fundamental magnitudes
involved in the law; they are derived from these constants (1957, p.346).

Campbell's paradigm of derived magnitude was density; a derivation of mass and
volume such that $D = M/V$. The constants estimated in instances of derived
measurements are real valued. For example, a particular composite material $x$ may have a
mass of 1.2 kilograms and a volume of .8 litre; hence its density is $1.2/0.8 = 1.5$ kg per L.
Other derived quantities include force, work, velocity and energy (Aitchison, 1970).

Within psychology, derived measurement (Campbell, 1921, 1957) may indeed suffer a
similar fate to that of fundamental measurement. So far, no-one has yet devised suitable
technologies that enable the search for system-dependent constants between psychological attributes. Physics has had such outstanding success with derived measurement (exemplified in dimensional analysis) as the causal influences are very well controlled to the point that over 99% of the variance in the dependent variable is attributable to the independent variables. Derived measurement in physics, however, is used without fail with those fundamental quantities already discovered through concatenation. Michell (1990, 1999) argues that derived measurement may be achievable in psychology if some future technologies could isolate one causal attribute from the confluence of both quantitative and non-quantitative structures that are thought to give rise to much of human behaviour. Such technologies, however, appear to be a long way off.

3.3 The theory of simultaneous, additive conjoint measurement (Luce & Tukey, 1964)

Although first published in 1964 by Luce & Tukey, the theory of conjoint measurement received the full axiomatic set theoretical treatment in the first volume of the Foundations of Measurement series (Krantz, et al, 1971). Krantz et al reaxiomatised the theory of conjoint measurement, with the consequent axioms totalling seven in number - 3 more than the original 1964 exposition. In this volume, the section on additive conjoint measurement included Krantz’s (1964) proof that additive conjoint structures were weakly ordered, solvable and Archimedean and could be concatenated like fundamental quantities. Krantz et al also provided the base from which Luce (1987) sought to investigate the Archimedean ordered group and also recognised Scott’s (1964) contribution to additive conjoint measurement in his hierarchy of cancellation conditions. Krantz et al also extended the basic ideas of additive conjoint measurement to develop a more advanced additive polynomial conjoint measurement theory, which included both multiplicative and additive composition rules.

To commence at test of the axiom of Krantz et al, all that is needed are two structures that possess ordinal information only. That is, their automorphic structure is $\infty$-point homogeneous and $\infty$-point unique (Narens, 1981a&b). Hence unlike derived measurement, axiomatic conjoint measurement does not require a priori that the structures are quantitative, although they may be found to be. This is a great boon to psychology which, lacking suitable concatenation operations, possesses many ordinal structures (Michell, 1990). The argument of axiomatic conjoint measurement is, however, that if these structures are quantitative, a strict simple ordering on the Cartesian
products of these structures resulting from a multiplicative composition rule will be forced by the satisfaction of the axioms of conjoint measurement as given in Definition 7 of Krantz, et al (1971, p.258). The following will explain conjoint measurement via each of the axioms given in turn.

The theory of axiomatic conjoint measurement has as its keystone concept the Cartesian product of sets. Let there be two sets $A = \{a, b, c\}$ and $X = \{w, x, y\}$. The Cartesian product of $A$ and $X$ is the set that does not contain any of the elements of $A$ or $X$ but of all the ordered pairs $(a, w)$ where $a \in A$ and $w \in X$ (Peterson & Hashisaki, 1967). The Cartesian product set $C = \{A \times X\}$ can be presented diagrammatically and thus the simple matrix of binomial multiplicative conjoint measurement results:

\[
\begin{array}{ccc}
  & a & b & c \\
 w & (a, w) & (b, w) & (c, w) \\
 x & (a, x) & (b, x) & (c, x) \\
 y & (a, y) & (b, y) & (c, y) \\
\end{array}
\]

Figure 3.1: Two non-empty sets can form the set of Cartesian products of all ordered pairs $(a, w), \ldots, (c, y)$.

In additive conjoint measurement, however, the composition rule is one of addition, such that $C = A + X$ (Krantz & Tversky, 1971). What this means that in Figure 1, the differences between the ordered pairs $(a, w), \ldots, (c, y)$ are being tested for additivity. For example, if it is discovered via independence that $(a, w) < (b, w) < (c, w)$ then $a < b < c$.

3.4 Axiom 1: Weak Ordering (Krantz et al, 1971, Definition 2 & Lemma 1, p.249).

Given the Cartesian product set $C = \{A \times X\}$, the ordered pairs $(a, w)$ and $(b, w)$ and that the independence axiom has been satisfied:

1. For $a, b \in A$ and given that $(a, w) \succeq (b, w)$ then $a \geq b$.
2. For $X, w \succeq x$ is defined similarly.
3. The relation "$\geq$" upon both $A$ and $X$ is transitive and connected.

Given these properties, both $A$ and $X$ are said to be weakly ordered. Note that the weak orders upon $A$ and $X$ are derived from the independence axiom holding upon $C$. This means that $A$ and $X$ do not have to display ordinal properties in the first instance.

This condition tests to see if the weakly ordered relation \( \geq \) holds upon \( C \). If it does, then \( \geq \) necessarily forces a weak order upon the sets \( A \) and \( X \). Krantz et al state that this is perhaps the most important feature of independence.

Formally, if \( \geq \) is a relation upon \( A \times X \) then it is independent iff for the elements \( a, b \in A \) for a certain element \( w \in X \) then \( a, w \leq b, w \) is implied for every element \( z \in X \), \( a, z \leq b, z \). And similarly for \( w, x \in X \) and \( c \in A \), then \( w, c \leq x, c \) implies for every element \( d \in A \), \( w, d \leq x, d \). This condition is called single cancellation by Michell (1990) and states that the ordering of every row in an additive conjoint matrix is independent of the ordering of every column and vice versa. The condition can be demonstrated diagrammatically as follows:

\[
\begin{array}{ccc}
  a & b & c \\
  \downarrow & \downarrow & \downarrow \\
  w & (a, w) & (b, w) & (c, w) \\
  \downarrow & \downarrow & \downarrow \\
  x & (a, x) & (b, x) & (c, x) \\
  \downarrow & \downarrow & \downarrow \\
  y & (a, y) & (b, y) & (c, y) \\
\end{array}
\]

Figure 3.2: Tests of independence upon \( C \), \( A \) and \( X \) in a simple 3 x 3 matrix. Note that the pairs are ordered from least \( (a, w) \) to the greatest \( (c, y) \) as the arrows are directed from less to greater.


The action of the independence axiom is necessary but not sufficient for the relation \( \geq \) to have additive representation. The pairs \( A + X \) must satisfy double cancellation for the differences between \( A \), \( X \) and \( A + X \) to be quantitative and the Thomsen condition is the weaker form of double cancellation.

Formally, the relation \( \geq \) upon \( A + X \) is said to satisfy double cancellation if and only if for every \( a, b, c \in A \) and \( w, x \) and \( y \in X \) if \( b, w \leq a, x \) and \( c, x \leq b, y \) then \( c, w \leq a, y \) must hold. If the \( \geq \) relation is replaced by \( \leq \), then the above is the weaker condition known as the Thomsen condition (Krantz et al, 1971).

Not all tests of double cancellation are independent of single cancellation or independence (Michell, 1988). If in any 3 x 3 additive conjoint matrix the independence
axiom is satisfied, the single test of double cancellation outlined above is sufficient for
the additivity of the "≥" relation upon A, X and A + X (Michell, 1988).

If, however, independence has not been tested then the number of double cancellation
conditions requiring testing in any 3 x 3 additive conjoint matrix is 3! x 3! = 36 (see
Michell, 1990, Fig.4.3, p.72). These 36 tests, however are also not logically independent
of one another. Rather, they form six separate groups of double cancellation conditions
which in each group, if one test of double cancellation holds, then all of them hold.
Hence, in order to test all 36 double cancellation conditions of any 3 x 3 additive conjoint
matrix, one test of double cancellation must be performed from each group. Such tests
are illustrated in Fig. 3.3.

If each of these six tests are satisfied, then independence and double cancellation are
both satisfied. Michell (1988) termed these instances of double cancellation Luce-Tukey
double cancellation as only they appeared in the original Luce & Tukey (1964)
exposition of additive conjoint measurement. If independence has already been tested,
with a < b < c and w < x < y then only the top left corner instance of double cancellation
needs testing as only it is logically independent of independence (Michell, 1988).

\[
\begin{array}{ccc}
    a & b & c \\
    \hline
    w \\
    x \\
    y \\
\end{array}
\]

Figure 3.3: The six tests of double cancellation needed for any 3 x 3 conjoint matrix in order to satisfy the
weak order, independence and double cancellation axioms of Krantz et al (1971). Arrows are directed from
less to greater. Open head arrows denote antecedent relations and the solid head arrows the consequent.

There has been, however, some confusion in the literature as to what are legitimate
tests of the double cancellation condition (Krantz & Tversky, 1971; van der Ven, 1980).
It has been held that some instances of double cancellation are no-test instances. That is,
certain algebraic relations upon the elements of $C$ cannot indicate either support or rejection of the Thomsen axiom. Such instances occur when the consequent relation is opposite to only one of the antecedent relations or that an equivalence relation constitutes either of the antecedent relations. Michell (1988, Table 1, p.468) showed that the ‘no-test’ category is actually empty. Certain permutations of the conjoint matrix are possible such that some ‘no-tests’ become acceptances. Rejection of the Thomsen axiom occurs only when the consequent algebraic relation is in a direction opposite to both antecedent relations (Michell, 1988). This convenient way of checking instances of double cancellation also appears in Michell (1990, Table 5.3, p.105).

For any additive conjoint matrix of size greater than 3 x 3, there exist other higher order instances of cancellation conditions that must be met in order to satisfy additivity. For example, Krantz et al (1971, p.251) argue that for any 4 x 4 additive conjoint matrix triple cancellation holds such that for $a, b, c, d \in A$ and $w, x, y, z \in X$, if $ay \geq bx, cz \geq dy$ and $dw \geq cx$ then $az \geq bx$. Indeed, there is a whole family of nth – order cancellation conditions. Scott (1964) gave their first exposition and a less technical presentation is given in Michell (1990).

3.7 Axiom 4: Restricted solvability / solvability (Krantz et al, 1971, Definition 5, p.256)

This axiom is similar to Hölder’s (1901), however, Krantz et al (1971), given their concerns that many empirical relational structures may have an upper bound, differentiate between restricted and unrestricted solvability. Unrestricted solvability holds for the relation “$\leq$” upon $C$ provided that for any three of the four elements $a, b \in A$ and $w, x \in X$, the fourth exists such the inequality $a, w \leq b, x$ is solved such that $a, w \sim b, x$. In restricted solvability, there exists the lower and upper bound elements $\tilde{b}, \tilde{h} \in A$ and $w, x \in X$ such that $\tilde{b}, x \geq a, w \geq \tilde{h}, x$; then there exists $b \in A$ such that $a, w \sim b, x$ (Krantz et al, 1971).

Solvability allows additive conjoint structures to exhibit independence; and in its unrestricted form, states that these structures are dense, infinite and unbounded like the real numbers. Indeed, Krantz et al (1971, Theorem 1, p.257) demonstrate that the independence axiom can be dropped iff the Thomsen condition is replaced by double cancellation and unrestricted solvability replaced by restricted solvability. These authors, however, caution against this due to acceptance of restricted solvability. With this form of solvability, there is the possibility that any empirical relational structure may not be
Archimedean nor Dedekind complete (Luce, 1987, argues that different forms of the Archimedean condition pertain to the different forms of solvability). With restricted solvability, elements of the structure may only be equally spaced.

In conjoint measurement with an additive composition rule, solvability demonstrates that for the difference $|x - y| \in X$ relative to any element $d \in A$ there is another element $e \in A$ such that $|x - y| = |d - e|$ (Michell, 1990). Importantly, the solvability of any additive conjoint matrix cannot be tested directly. It can only be tested indirectly through the test of the hierarchy of cancellation conditions (Michell, 1990). For any 3 x 3 conjoint matrix, these are all the tests of independence and Luce – Tukey double cancellation (Michell).


In additive conjoint measurement, the Archimedean axiom ensures that no difference between any of the conjoint matrix components $A$ and $X$ is infinitely greater, or conversely, infinitely smaller than any other difference. Satisfaction of this axiom means that the magnitude of any difference between any of the elements of the components of an additive conjoint structure is finite, relative to another difference (Michell, 1990). An additive structure possessing the Archimedean property is a finitely bounded standard sequence (Krantz, et al, 1971).

To define the Archimedean condition, Krantz et al (1971) argue that for any set of positive, negative, finite or infinite integer $N$, there exists sets based upon the sets $A$ and $X$ such that $A' = \{a_n | a_n \in A, n \in N\}$ and $X' = \{x_n | x_n \in X, n \in N\}$. These sets are standard sequences on $A$ and $X$, respectively. This means that for $A$ there exists $w, x \in X$ such that for all $n$ and $n + 1 \in N$, $a_n w \sim a_{n+1} x$; and for $X$, there exists $a, b \in A$ such that for all $n$ and $n + 1 \in N$, $x_n a \sim x_{n+1} b$. What this means in an additive conjoint measurement matrix is that relative to the difference $|b - a|$ in $A$, there exists a series $x_1, x_2, ..., x_n \in X$ such that a standard sequence of differences equal to $|b - a|$ results, such that $x_1 - x_2 = x_2 - x_3 = ... = x_n - x_{n+1} = b - a$. The same argument holds for $X$, such that $a_1 - a_2 = a_2 - a_3 = ... = a_n - a_{n+1} = x - w$ (Michell, 1990). For elements $a, b, c, d \in A$ and $w, x, y, z \in X$ if $b - a < d - c$ and $x - w < z - y$, then for any natural number $\phi$, $A$ and $X$ are Archimedean iff $\phi(b - a) \geq d - c$ and $\phi(x - w) \geq z - y$, respectively (Michell, 1990).
Of course, satisfaction of the Archimedean condition logically rests on solvability being satisfied. Without solvability, there could not exist the elements $d \in A$ and $z \in X$ which define $A$ and $X$ as Archimedean. Thus there could not be the infinite number distances between the elements within $C$, $A$ and $X$. Like solvability, however, the Archimedean condition in additive conjoint measurement cannot be directly tested. It must be tested indirectly using the hierarchy of cancellation conditions (Scott, 1964, Michell, 1990).


According to the classical theory of measurement, empirical satisfaction of the above axioms demonstrates that the differences between the elements within $A$ and $X$ are quantitative. This means that given $a, b \in A$ and $w, x \in X$ and any positive real number $\phi \in \mathbb{R}^+$:

$$\frac{|b - a|}{|x - w|} = \phi \text{ or } b - a = \phi(x - w)$$

According to the representational theory of measurement, there exist interval scale homomorphisms from the sets $A$ and $X$ into the set of the real numbers $\langle \mathbb{R}, \leq, S_0, S_1, \ldots, S_n \rangle$. Given $a, b \in A$ and $w, x \in X$ and real-valued functions $\psi$:

$$a, w \leq b, x \text{ iff } \psi_1(a) + \psi_1(w) \leq \psi_1(b) + \psi_2(x)$$

Given two other real-valued functions $\psi_1'$ and $\psi_2'$, then there exists real-valued constants $\varepsilon_1$ and $\varepsilon_2$, $\alpha > 0$ such that:

$$\psi_1' = \alpha \psi_1 + \varepsilon_1 \text{ and } \psi_2' = \alpha \psi_2 + \varepsilon_2$$

Thus $A$ and $X$ are able to be measured using interval scales with a common unit $\alpha$. Luce & Tukey (1964) argued that iff $\psi_1 = 0 = \psi_2'$, then $A$ and $X$ are measurable using ratio scales with a common unit.

Hence the power of the theory of additive conjoint measurement to discover additivity within two non-interactive ordinal structures not capable of the process of physical concatenation. Yet additive conjoint measurement is merely a more general form of the physical processes of fundamental and derived measurement (Michell, 1990). In order to illustrate the use of additive conjoint measurement, an example will be made of its application to psychology.
3.10 An application of conjoint measurement to a psychological attribute

Applications of conjoint measurement to psychological attributes thought or assumed to be quantitative are few and far between. The entrenchment of Stevens’s (1946) theory of measurement (Michell, 1997b); the diminishing presence of measurement theory in the psychology curricula (Aiken, et al, 1990); the alleged difficulty of the subject matter and the problem of error (Cliff, 1992); and the youth of additive conjoint measurement theory as compared to psychometrics all contribute to the relative absence of measurement theory in the substantive areas of psychology. It has only found use in decision making and utility theory (Luce, 1996, 2000); in attitudes towards homosexuality (Michell, 1994); item difficulty in education (Green, 1986); in the psychophysics of loudness (Schneider & Cohen, 1997; Huebner & Ellemeyer, 1993; Luce, 1972); and in ergonomics (Vidulich & Tsang, 1986). The eclectic nature of its application give the impression that additive conjoint measurement theory is seen by the few psychologists who know of its existence as having more novelty than scientific value. Apart from Luce and his associates with utility theory and Michell with attitudes, no-one has used the theory systematically in a particular substantiative area.

Despite the overwhelming importance of the following concept to psychology, the only application of additive conjoint measurement to intelligence has been with Stankov & Cregan (1993). That it is the only study to have provided evidence that intelligence may be quantitative is testament to psychology’s perpetual ignorance of measurement theory; especially when the study is placed in the context of an entire century’s worth of study into intelligence. This makes it ideal for use as an illustration of the application of additive conjoint measurement theory to psychology.

The primary aim of Stankov & Cregan (1993) was to conduct a study into intelligence to see if the attribute possessed “measurement properties”, that is, additive structure. Drawing from cognition, these researchers took the view that intelligence consists of elementary intellectual abilities. This view presents difficulties from a measurement perspective as it argues that intelligence is an additive function of some other underlying attributes. If indeed intelligence is both quantitative and sustained by these elemental attributes, these latter attributes must be scientifically examined for additive structure at some point. Fortunately, the theory of additive conjoint measurement has a limited capacity to deal with this situation in its basic $P = f(A, X)$ form; where $A$ and $X$ are two such elemental abilities. Stankov & Cregan used additive conjoint measurement in this way, but unfortunately argued that $P$ has to be operationalised in terms of $A$ and $X$. There
is no necessity to do this and it creates the problems mentioned in Chapter 3 associated with operationalism. Apart from this, their study was methodologically sound.

As stated earlier, the general form of the additive conjoint structure is of the Cartesian products \((P)\) formed by two at least ordinal structures \(A\) and \(X\) and some additive, non-interactive function \(f\). For structure \(A\), Stankov & Cregan devised a 3 level ordinal item difficulty structure. The apparatus they used to order item difficulty was a letter series completion task; in which a subject is presented with a series of letters, such as M, B, O, B, Q, B, S and is asked to provide the next three letters (which are B, U, B). The rule this letter series follows is \([X_1 + 2(X_1), C_1]\) if \(X_1\) is set at \(M\) and \(C_1 = B\). Of course, this method assumes that subjects have a correct understanding of the order of the alphabet. Stankov & Cregan argued that these tasks can be ordered in terms of difficulty by increasing the number of ‘operators’ (denoted \(+N()\); \(+2(X1)\) in the previous rule) or ‘working memory placekeepers’. The more operators a letter series rule has the more difficult the series is to complete. For the three levels of \(A\), Stankov & Cregan had 15 letter series tasks with one operator, 15 with two operators and 15 with three.

For structure \(X\), Stankov & Cregan devised a motivational ordinal structure. Each subject was presented with all 45 letter series completion tasks under three motivational conditions. The first condition merely informed subjects to complete the tasks as quickly and accurately as possible. The second condition informed subjects that they had 75% of the time they had to complete the 45 tasks under the first motivational condition, and thus they had to work more quickly to finish them. The third condition was the same as the second except subjects were told that they only had 50% of the original time available. In each condition, however, all subjects were given time to complete all 45 tasks.

Stankov & Cregan averaged the number of correctly completed letter series tasks and averaged the times it took subjects to complete the tasks and used these averages as elements of \(P\). Instead of using all the conditions of double cancellation to test independence, Stankov & Cregan used null hypothesis testing in the form of the paired samples t-test on the appropriate \(P\) elements. By directly testing independence in this way only one test of the double cancellation condition was necessary, which Stankov & Cregan also tested using the paired samples t-test. Both the independence and double cancellation axioms of conjoint measurement were taken to be satisfied using both types of data, given that a simple order on \(P\) was indicated by the t-tests being highly statistically significant. Unfortunately, Stankov & Cregan did not calculate the power of their statistical analyses, so there was no indication of how affected the analyses may
have been by Type 1 error (Cohen, 1988). Nevertheless, it was a logical use of null hypothesis testing to control error, the major problem facing applications of additive conjoint measurement in the behavioural sciences (see Falmagne, 1976 for another statistical method).

Stankov & Cregan concluded that fluid intelligence, via its operational definition as performance on the letter series completion tasks, possess additive structure. This was a somewhat premature conclusion that overextended their findings. The evidence revealed by their study was that item difficulty, as a psychological attribute, may have additive structure. Their attempt to marry operationalism with conjoint measurement was logically incorrect and did nothing to enhance the study - an indication that even those psychologists courageous enough to use additive conjoint measurement in their research find it hard relinquishing the operationist modus operandi.

Stankov & Cregan also concluded that the letter series task was an appropriate measure of fluid intelligence (a conclusion which apparently did not conflict with the role of the former as an operational definition of the latter). No such evidence to support this conclusion was forthcoming from this study. The letter series completion task does not yet identify magnitudes of fluid intelligence, compare them with a standard magnitude of fluid intelligence and thus identify ratios. Until this is done, it cannot be argued that any apparatus that is used to order levels of a psychological attribute is actually a measure of that attribute. It is for this ultimate purpose- the identification of magnitudes and hence ratios- that axiomatic conjoint measurement is to be used in psychology.
Chapter 4: The development of the concept of subjective control in addiction to alcohol and addiction to gambling

It is not the aim of this chapter to present an overview of addiction to alcohol and addiction to gambling. This has been done very well elsewhere (e.g., Dickerson & Baron, 2000; Dickerson, 1989; Sobell & Sobell, 1995; Orford, 1985, 2001) and the reader is referred to these sources. The aim of this chapter is to take the perspective of the quantitative psychologist interested in axiomatic measurement theory and apply it in an analysis of the historical development of one of the addiction area’s most important concepts – subjective control. Importantly, the chapter will focus on the development of subjective control as a quantitative attribute and will then propose a new definition of the concept that may be amenable to testing by the theory of additive conjoint measurement (Luce & Tukey, 1964).

It is important to note that the concept of subjective control does not have its origin in the psychological literature written on addiction. Nor should subjective control be confused with Julian Rotter’s locus of control theory; the latter being a social learning theory of personality which originates in the psychological sub-discipline of individual differences (Phares, 1991). As a serious, scientific concept, subjective control has its origins in the discipline of medicine (Levine, 1978). The scientific attention the concept has received has been largely in the medical literature as it has long been speculated as a possible causal attribute of one particular and pernicious addiction – that of the excessive consumption of alcohol.

4.1 “Loss of control” and the medicalisation of alcoholism

In the very late 18th to early 19th centuries, the young discipline of modern medicine argued that addiction to alcohol was a physical disease (Levine, 1978; Miller, 1983) rather than either an emotional state of excessive ‘love’ for the substance or poor moral fibre. Levine (1978) argued that the famous U.S. physician Benjamin Rush was the first to argue that the major identifying symptom of the disease was the ‘loss of control’ that an alcoholic displayed during a bout of drinking. An alcoholic was said to have ‘lost control’ of his drinking when, contrary to his desires not to, he could not help drinking successive drinks after the consumption of the first drink until he was completely inebriated:

When strongly urged, by one of his friends, to leave off drinking [an habitual drunkard] said, “Were a keg of rum in one corner of a room, and were a cannon constantly discharging
balls between me and it, I could not refrain from passing before that cannon, in order to get at the rum" (cited in Levine, 1978, p.152).

Miller (1983) argued that the physician Gaupp also identified a condition called *dipsomania* – a medical syndrome incorporating both loss of control and irresistible cravings for alcohol. This early disease concept of alcoholism used the frequency of which an alcoholic consumed alcoholic beverages as an index of lost volitional control. Rush argued:

> It belongs to history of drunkenness to remark, that its paroxysms occur, like the paroxysms of many diseases, at certain periods, and after longer or shorter intervals. They often begin with annual, and gradually increase in their frequency, until they appear in quarterly, monthly, weekly, and quotidian or daily periods (cited in Levine, 1978, p.152).

Hence lost volitional control was understood to be a dispositional concept in that it was defined in terms of the effects it generated. What this means is that ‘loss of control’ was defined in terms of the frequency of alcoholic beverages consumed. Defining a concept as a disposition to produce a class of effects has the limitation of obscuring any intrinsic properties that the concept may possess (Michell, 1999). Defining ‘loss of control’ in the above manner achieves exactly this. This tendency to define subjective control dispositionally has persisted.

Nevertheless, the early medicalisation of alcoholism was very important. It effected the scientific understanding of addiction, the scientific observation of the behavioural phenomena associated with addiction or ‘symptoms’, and the argument that the diseases of addiction could be treated. Most importantly, as an alcoholic’s subjective, volitional control over his behaviour was a symptom, this meant that poor control over drinking behaviour had to be present in every diagnosis of the disease of alcoholism. This in turn meant that an alcoholic’s control over his or her drinking behaviour had to be conceptualised into a symptom of ‘loss of control’. Thus ‘loss of control’ became central in diagnoses of alcoholism.

It follows that the successful treatment of any disease necessarily requires the absence of the symptoms peculiar to that disease. For the disease of alcoholism, this meant the elimination of the symptom of ‘loss of control’. The simplest method by which to eradicate ‘loss of control’ was to prevent the alcoholic from ingesting even one alcoholic beverage. Benjamin Rush offered the complete abstinence from alcohol as the only possible ‘cure’ for the disease, as he had identified the substance of alcohol as the sole causal agent:
My observations authorize me to say, that persons who have been addicted to them, should abstain from them suddenly and entirely. 'Taste not, handle not, touch not' should be inscribed upon every vessel that contains spirits in the house of a man, who wishes to be cured of the habits of intemperance (cited in Levine, 1978, p.152).

4.2 The disease theory of alcoholism - E.M Jellinek (1960)

The passing decades and the unprecedented explosion in medical science and technology did little to erode the importance of 'loss of control' in alcoholism research. The establishment of Alcoholics Anonymous in 1935 reinforced the idea that every alcoholic did indeed suffer from a permanent loss of volitional control over the ingestion of alcohol (Miller, 1983). The centrality of this concept in the diagnosis of alcoholism was reinforced by the influential scholar E.M. Jellinek. Jellinek's (1960) most important work was his monograph The Disease Concept of Alcoholism. The book was largely built on two quite expansive and exhaustive reviews of alcoholism that Jellinek co-authored (Bowman & Jellinek, 1941a & b). In his text, Jellinek reinforced the medical perspective of addiction and firmly cemented the definition of the concept of 'loss of control':

Recovered alcoholics in Alcoholics Anonymous speak of "loss of control" to denote that stage in the development of their drinking history when the ingestion of one alcoholic drink sets up a chain reaction so that they are unable to adhere to their intention to "have one or two drinks only" but continue to ingest more and more often with quite some difficulty and disgust – contrary to their volition (Jellinek, 1960, p.41).

The most important predicate in Jellinek’s definition is ‘contrary to their volition’ as it is volitional capacity which differentiates the drinking behaviour of an alcoholic from the behaviour of someone drinking in a careless manner. To clarify this distinction, Jellinek termed the behaviour of the latter person undisciplined drinking as such drinking is only:

"... a deliberate transgression of the social rules (admittedly diffuse rules) relating to amounts, times, occasions and locales of drinking. In order to avoid the suggestion of loss of control in this latter drinking behaviour, the use of the expression undisciplined drinking seems to be more appropriate, particularly since the drinker in these instances is not deprived of free choice." (p.46, original emphasis)

In other words, the drinking behaviour of a non-addict binge drinker cannot be identified with the drinking behaviour of an alcoholic, even though the consumption of one beverage leading to the consumption of several more may occur in both drinkers, as the non-addict binge drinker is not deprived of the facility to volitionally moderate or cease his or her behaviour. Furthermore, rules are arbitrary human conventions which obviously do not necessarily govern all human behaviour whilst diseases are non – trivial
biological conditions that are beyond the capacity of the will to control. During binges, a binge drinker is merely choosing not to exercise the control prescribed by the appropriate rules. Jellinek argued that an alcoholic had no such choice.

Departing from Rush, Jellinek did not think that the sole causal agent of the disease was the substance of alcohol itself. Rather, Jellinek considered the alcoholic’s ‘loss of control’ to have two distinct causal components. Firstly, the severe withdrawal symptoms emanating from the discontinuation of alcohol ingestion after a prolonged period of heavy alcohol intake leads, after one initial drink, to the ingestion of several successive drinks so as to relieve these symptoms. Secondly, when withdrawal symptoms are either not present or have been satiated, intense anxiety possibly emanating from the failure of a single alcoholic drink to produce the psychological sensation of euphoria leads to the ingestion of several further drinks to alleviate this anxiety. Jellinek stated:

The demand for alcohol seems to be of a twofold nature. One part reflects the necessity to allay the distressing withdrawal symptoms, ie a physical demand; the other part reflects the obsessive belief that ultimately a sufficient amount of alcohol will bring about the tension reduction which, before the loss of control, was achieved quite easily (p.146).

Jellinek speculated that anxiety in alcoholics was due to the biological phenomenon known as the short-range accommodation to alcohol of the central nervous system. This phenomenon is observed when a particular blood alcohol concentration is selected (eg 0.05%), the psychologically impairing effect of this particular concentration is higher during the ascending phase (when blood alcohol levels are increasing) than it is during the descending phase. This effect has been noted in both alcoholics and non-alcoholic drinkers (Jellinek, 1960), however, with the former group, the discrepancy in psychological impairment between the ascending and descending phases is much less than what it is in non-alcoholic drinkers. This difference between the two groups of drinkers, Jellinek speculated, was the biological cause of the psychological component of ‘loss of control’. Although stating that there was a lack of empirical evidence supporting the existence of such a causal mechanism, Jellinek nonetheless concluded:

The loss of control which is described by members of Alcoholics Anonymous as well as by students of alcoholism as the inability to stop after one or two glasses… seems to be characterised by minor withdrawal symptoms in the presence of alcohol in the blood stream and the failure to achieve the desired euphoria for more than a few minutes. These symptoms explain superficially the behaviour observed in the so-called loss of control and they suggest a combination of short-range accommodation of nervous tissue with long-range acquired increased tolerance (p.147).
4.3 Empirical rejection of the “loss of control” thesis

In the decade after the publication of Jellinek’s seminal work, the disease concept of alcoholism was seriously challenged scientifically. This challenge was precipitated by a series of experiments conducted in the 1960s to early 1970s which sought to put Jellinek’s (1962) ‘loss of control’ thesis to the empirical test (for example, Bailey & Stewart, 1967; Cutter, Eugene, Schwaab & Nathan, 1970; Davies, 1962; Engle & Williams, 1972; McNamee, Mello & Mendelson, 1968; Merry, 1966). This research found Jellinek’s thesis to be untenable. The papers cited above collectively found that between three and 30% of study participants who were alcoholics were able to drink without experiencing ‘loss of control’ (Engle & Williams, 1972). The most outstanding work, however, was conducted by the psychologists Mark and Linda Sobell. So influential was the work conducted by these two scholars that not only was Jellinek’s (1960) concept of ‘loss of control’ discredited, the treatment goal of total abstinence was also undermined. The consequent success of the Sobells’ novel form of treatment completely changed both the medical and psychological view of addiction to alcohol (Marlatt, 1983).

Sobell, Sobell & Christelmann, (1972) found in an interview study of 30 alcoholics that 19 reported being able to stop drinking after the ingestion of one drink. To test this finding, Sobell et al conducted a second experimental study which found that out of a group of 101 hospitalised alcoholics, only 2 found it necessary to leave the hospital to consume more alcohol after all participants had consumed one alcoholic drink. The findings, in accordance with previous research, became a foundational study of the Sobells’ groundbreaking, ‘controlled drinking’ treatment of alcoholism known as Individualised Behaviour Therapy (IBT) (Mills, Sobell & Schafer, 1971; Sobell & Sobell, 1973a). This therapy was specifically designed not to induce abstinence from drinking amongst hospitalised alcoholics, but rather to effect patterns of controlled, social drinking. In this respect it differed enormously from all other previous forms of therapy, which by historical design encouraged abstinence as the treatment goal. The Sobells perceived alcoholism as a learnt behaviour and hence their controlled drinking treatment centred on teaching alcoholics to drink at socially acceptable levels.

By the end of an IBT program, alcoholics have displayed increased drinking of mixed drinks, decreased drinking of straight drinks, a decrease in the number of drinks ingested and a slowing in the rate of the digestion of one drink. Sobell & Sobell (1973b) conducted a one year follow up study of their original (1973a) participants. Participants
who had undergone IBT had better control over their drinking behaviour than did those in a control group who undertook therapy aimed at inducing abstinence. Sobell & Sobell (1976) conducted a second year follow up study which confirmed the first year results.

But not all agreed. An article (Pendery, Maltzman & West, 1982) appeared in the prestigious journal *Science* which severely criticised the original Sobell & Sobell (1973a) study. Pendery et al conducted a 10 year follow up of the original participants and found that only one had maintained a pattern of controlled drinking. Six had resorted to abstinence, 4 had died from alcohol related causes and 8 continued to drink excessively. All had at some stage had rehospitalised. Pendery, et al. concluded that the claims of Sobell & Sobell (1973 a & b, 1976) were fraudulent.

This article ignited a storm of controversy which resulted in a slander campaign by the North American tabloid media that muddied the Sobells’ reputations (Marlatt, 1983). So bad was the political fallout that the Canadian Addiction Research Foundation, which employed the Sobell’s at the time, commissioned an independent inquiry into the Sobell’s work. After poring through the Sobell’s data, the inquiry found no evidence to suggest that the Sobells had falsified any of their data and thus the inquiry exonerated the Sobells of all charges of academic fraud (Marlatt, 1983).

In 1995, the prestigious journal *Addiction* published a special issue in which the Sobells were the guest editors. Sobell & Sobell (1995,p.1149) stated that three conclusions could be drawn after 25 years of research:

1. Recoveries of individuals who have been severely dependent on alcohol predominantly involve abstinence.
2. Recoveries of individuals who have not been severely dependent on alcohol predominantly involve reduced drinking.
3. The association of outcome type and dependence severity appears to be independent of advice provided in treatment.

These conclusions reflected the findings of scholars other than the Sobells who found that alcoholics who responded to IBT: were less likely to be institutionalised, displayed fewer symptoms, were less likely to consider themselves as alcoholics, were less likely to have abstinence as a treatment goal and had a relatively recent onset of their disorder than did alcoholics who were severely physically dependent (Miller & Joyce, 1979; Orford, 1973). Thus the initial premise of the Sobells that all alcoholics could be treated by IBT was incorrect (Sobell & Sobell, 1995).

Nevertheless, the Sobells’ activities were highly influential both theoretically and in the treatment of addiction to alcohol. Jellinek’s (1962) ‘loss of control’ thesis appears
pertinent only to those suffering severe physical dependence to alcohol. This is something Jellinek himself might have discovered if he put his own theory to the empirical test (Kahler, Epstein & McCrady, 1995). It was also found, however, that social drinkers who could not be classified as alcoholics sometimes experienced losing control over their drinking (Storm & Cutler, 1975). The Sobell’s work had initiated epidemiological studies that found large populations of alcoholics that had symptoms of low severity; populations that responded well to IBT (Sobell & Sobell, 1995). A broader concept of subjective control, however, did not fill the conceptual vacuum left by the rejection of the ‘loss of control’ thesis.

4.4 The Alcohol Dependence Syndrome (ADS) (Edwards & Gross, 1976) and the concept of “impaired control”

After the empirical studies of the Sobells and others were conducted, it was no longer tenable to argue that ‘loss of control’ was a sufficient condition for the diagnosis of alcoholism. The results of these studies showed that people suffering from their drinking behaviour may or may not display the volitional ability to control the intake of alcohol. As a result, a distinctive emphasis on the necessity of understanding alcoholism by closely studying the personal experience of alcoholics arose in the alcohol literature. A review article in this particular literature articulated the necessity for a fresh theoretical understanding of alcoholism in the light of the recent discoveries. This article was written by British psychiatrists Edwards & Gross (1976) and in it they proposed a new theoretical model of alcoholism called the alcohol dependence syndrome (ADS). So influential was this new theory that the term ‘alcoholism’ was deleted from the International Classification of Diseases by the World Health Organisation in 1976 and in its place the alcohol dependence syndrome introduced in 1979 (Shaw, 1979). This model of addiction to alcohol was to greatly influence all future research into the condition (Heather et al., 1993; Sobell & Sobell, 1995).

Despite its standing, the alcohol dependence syndrome is essentially a ‘grab-bag’ concept which forces together a variety of (possibly unrelated) psychological, biological and social phenomena deemed by Edwards & Gross (1976) as associated with addiction to alcohol. These phenomena were called the elements of the syndrome and Edwards & Gross classified them along seven separate ‘dimensions’. These are: the narrowing of the drinking repertoire; salience of drink seeking behaviour; increased tolerance to alcohol; repeated withdrawal symptoms; avoidance or relief of symptoms by further drinking; subjective awareness of compulsion to drink; and reinstatement of drinking after a period
of abstinence. The attribute of subjective control was forced by this classification into those behaviours that clustered around the theme of ‘subjective awareness of a compulsion to drink’. Edwards & Gross (1976) argued:

It is unclear, however, whether the experience is truly one of losing control rather than one of deciding not to exercise control. Control is probably best seen as variably and intermittently impaired rather than ‘lost’ (p.1060).

Here the traditional concept of ‘loss of control’ received its first formal reworking into the attribute of ‘impaired control’, but this new concept did not take the standing that ‘loss of control’ once enjoyed. In their remaking of the medical and psychological understanding of alcoholism, Edwards & Gross did not explicate whether ‘impaired control’ was a causal attribute, symptom or mere epiphenomenon of alcoholism. Neither did they attempt to identify any possible relations between all of the psychological phenomena within the alcohol dependence syndrome; and merely argued that:

.....we take the term syndrome to mean no more than the concurrence of phenomena. Not all elements need always be present, nor always present with the same intensity. No assumption need be made about the cause or the pathological process.... (p. 1058, my emphasis).

This neglect of the very important scientific task of identifying structure and the relations of cause and effect was deliberate. Publishing in the medical literature, Edwards & Gross were primarily interested in establishing alcoholism as a clinical syndrome. This professional interest necessitates elucidating any behavioural phenomena associated with alcoholism as such phenomena can be used by medical practitioners in the field as identifying symptoms of the syndrome\(^{20}\). Hence the following reasoning:

It is fully in accord with the development of medicine that a syndrome should occasionally be recognised considerably before its scientific basis can be determined (p.1061). Edwards et al (Note 1) emphasise the need “to identify and treat the underlying dependence syndrome, rather than dealing only with the presenting physical, mental and social disabilities that may cluster around the syndrome” (Edwards, Gross, Keller, Moser & Room, 1977, p.6, cited in Skinner & Allen, 1982, p.206).

Thus the remaking of alcoholism into a dependence syndrome was shaped by the practicalities of medical diagnosis and treatment rather than by the scientific necessity of investigating cause, effect and structure. As a result, the new concept of impaired control remained a dispositional concept like the ‘loss of control’ one it supposedly superseded. ‘Impaired control’ was simply viewed by medical practitioners as both indicative of a

\(^{20}\) Miller (1976, p.649) states: “The usefulness of a diagnosis lies in the description of a consistently intercorrelated set of symptoms (ie a syndrome) with implications for prognosis, treatment and prevention.”
medical syndrome and a disability thereof; and its structure and role in addiction was of no concern in itself.

The alcohol dependence syndrome, however, did not escape criticism. Shaw (1979) made a penetrating critique of the syndrome and its acceptance by the World Health Organisation. Firstly, he argued that rather than supplanting Jellinek's (1960) work, the alcohol dependence syndrome was simply a recast of Jellinek's (1960) ideas into a single mould as it actually maintained the impairment of subjective control over drinking as the key symptom. Shaw questioned the actual existence of this attribute and proposed that subjective control was nothing more than a psychic epiphenomenon arising from the malfunctioning biochemistry of an alcoholic's central nervous system:

These components, although very real feelings to those who experience them, might be more meaningfully seen not so much as existent phenomena in themselves as rather psychic interpretations of the effects of increasing tolerance and/or increasing withdrawal coupled with other motivations for drinking (p.341).

Secondly, Shaw argued that the syndrome had no more clinical utility than did Jellinek's (1960) taxonomy of alcoholics and suggested that all the syndrome did in this regard was to label people as 'alcohol dependent' rather than as 'alcoholics'. On this point, the syndrome did not place individuals on a continuum of severity of a compulsion to drink alcohol but merely labelled them as either dependent or non-dependent. Thirdly, that the syndrome presented no great insights for scientific research as "...the syndrome idea, like the concept of alcoholism, diverts attention away from predisposing or compounding causes of drinking problems other than the effects of alcohol per se." (p.345, original emphasis). Thus Shaw had highlighted the dispositional trait arguments underlying the ADS. Its acceptance also prevented the investigation of "...the possibility of interactive relationships between these phenomena [of the syndrome] and those at other levels of experience." (p.346). Fourthly, that the ADS was perhaps only a political child:

Since research had 'undermined the credibility of the simple notion of alcoholism as a discrete and fixed entity', there may have been a felt political need to find a substitute 'entity' which did have a scientific and medical credibility and which ideally could be classified as a disease....In advance of 'further elucidation', it must be concluded that the promotion of the syndrome to international terminology was a 'cultural and political decision' rather than a purely academic decision (p.346).
Shaw’s criticisms were serious; the particularly debilitating one being his refutation of the existence of subjective control. In a commentary on his paper, Madden (1979) objected to this rejection and stated:

Reduced control of alcohol intake is not merely a subjective feature noticed by alcoholics, it is also readily deducible by an observer from the nature and consequences of their drinking (p.350).

Madden here was correct. A consumer of alcoholic beverages can be independently observed to manifest either a total or impaired volitional ability to control the intake of alcohol. Control is not a trivial phenomenon and can be falsified as it can be observed scientifically. Furthermore, Madden argued that subjective control over drinking is not purely governed by awry central nervous system biochemistry. Lapses in control often both have environmental triggers such as the features of places and events associated with heavy drinking and stressors; and psychological triggers, such as emotions and mood states as suggested by Jellinek (1960).

Unfortunately, most of Shaw’s concerns went unaddressed. Madden’s other replies were less than sharp and stated that whilst the alcohol dependence syndrome possessed ‘heuristic value’ (p.351), the omission of the term ‘syndrome’ from the model would circumvent the remainder of Shaw’s criticisms. This is not so. Shaw was correct in pointing out that the alcohol dependence syndrome did not make arguments for the possible role of psychological attributes external to the ADS model influencing alcohol dependence; and he was correct in stating that the possible relationships between the attributes within the model were not examined by Gross & Edwards (1976). Shaw’s claim that this state of affairs may have been due to the syndrome being a political creation rather than a scientific one is intriguing but lacking in evidence. Edwards (1986, p.173) later stated: “Shaw’s analysis is provocative, but needs to be tested against a more complete historical analysis”. It must be noted that at no stage did Gross & Edwards (1976) argue that the syndrome was beyond critical scientific investigation. Shaw’s major concern was the attribute of subjective control being arbitrary and perhaps trivial and at no point did either Gross or Edwards address this.

4.5 The ADS and “impaired control” as measurable and quantitative psychological phenomena

The development of the alcohol dependence syndrome formally brought to the attention of alcoholism researchers a variety of psychological phenomena that could be investigated. Importantly, Edwards & Gross (1976) proposed that the alcohol dependence syndrome was more than just a ‘grab-bag’ of symptoms, but a unitary construct of
alcoholism. Edwards & Gross argued that the syndrome, in addition to being unidimensional, was also quantitative as they stated: "...we need to see dependence in terms of degrees rather than absolutes" (p.1061) and "All these elements [of the syndrome] exist in degrees thus giving the syndrome a range of severity. They represent the dimensions along which the clinician can order the information given to him..." (p.1058). Edwards & Gross provided no empirical evidence to support the claim that the ADS and its constituent elements were quantitative. Edwards (1986, p.173) later reiterated his stance that the identification of a syndrome of alcoholism enabled the severity of addiction to alcohol to be ordered along a single dimension or continuum:

A tension may be detected between the categorical implications of a syndrome and the continuous nature of a dimension but here again the contradiction may be more apparent than real: the syndrome is that which allows us to identify a dimension. Where the question of continuity versus discontinuity does however become real, is around the issue of whether the normal and clinical populations lie along the dimension as a single distribution.

Shortly after the publication of Edwards & Gross (1976), most researchers accepted the theory of the alcohol dependence syndrome and considered it a continuous, onedimensional psychological attribute (Ludwig, Bendfelt, Wikler & Cain, 1978; Stockwell, Hodgson, Edwards, Taylor & Rankin, 1979). Stockwell et al went so far as to proclaim:

The syndrome of alcohol dependence is given expression and, in various ways, both facilitated and hindered by an individual's personality and general circumstances, but remains, nevertheless, a unitary syndrome (p.79).

Unable to resist the ideas of quantity and measurement in mainstream psychology, researchers (Chick, 1980a & b; Davidson, Bunting & Raistrick, 1989; Heather, Tebbutt, Mattick & Zamir, 1993; Kahler, Epstein & McCrady, 1995; Skinner & Allen, 1982; Stockwell, et al, 1979) hypothesised that the syndrome was quantitative. Skinner & Allen (1982) noted:

Both the alcohol dependence syndrome and alcohol related disabilities are viewed as existing in degrees rather than in an all-or-none state (Edwards, et al, Note 1). This emphasis on quantitative variation among individuals is a significant departure from the categorical diagnoses of the National Council on Alcoholism (1972) and American Psychiatric Association (1980) (pp.199-200, my emphasis).

Impaired control, despite being "... a cardinal element in the alcohol dependence syndrome" (Skinner & Allen, 1982, p.199), remained both a disposition to effect a high frequency of alcohol consumption and a minor sub-component within the ADS.
4.6 The introduction of classical test theory psychometrics to ‘impaired control’ -
the factor analysing of the ADS

This assumption of quantity necessarily led to the assumption that the syndrome was
measurable. Both the proposed unidimensionality and deliberately multifaceted structure
of the syndrome with its variety of associated phenomena made the syndrome very
attractive to those researchers trained in the multivariate statistical procedures of
psychometrics, especially factor analysis. Factor analysis is the sine qua non method of
assessing an attribute for unidimensionality in mainstream psychology\textsuperscript{21} and in
alcoholism research it has not been any different. This was noted by a prominent
alcoholism researcher:

Factor analysis gives rise to several criteria against which to test a hypothesis of unitariness.
Different authors in the alcohol literature have used different criteria but the common
feature is a demonstration that the major factor accounts for a very substantial part of the
variance [of scores in psychometric tests of alcohol dependence syndrome] (Chick, 1980b,
p.266).

Edwards and his colleagues argued of the utility of factor analysis in understanding the
syndrome:

\ldots the alcohol related disabilities of any individual are susceptible to the same multifactorial
analysis whether that person is or is not alcohol dependent (Edwards, Gross, Keller, Moser
& Room, 1977; cited in Shaw (1979, p.342), original emphasis)

Edwards (1986, p.174) later publicly supported the use of factor analysis in the
assessment of the alcohol dependence syndrome:

If, as postulated, the elements in the syndrome more or less hang together, then a variety of
statistical approaches should be able to demonstrate this coherence. The statistical technique
which has so far been favoured is the application of factor analysis. Identification of a factor
which loads on appropriate items might be taken as validation of the syndrome concept, and
the failure of any element to load on this dimension might suggest that it is not part of the
syndrome.

Unfortunately, the attempted assessment of the alcohol dependence syndrome suffered
from some of the worst excesses of this kind of psychometrics. By 1979, merely three
years after the publication of the Gross & Edwards (1976) article, there were at least 300
psychometric questionnaires which purported to measure either all or some of the
elements of the syndrome (Stockwell, et al, 1979)\textsuperscript{22}. Edwards and his associates
(Stockwell, Hogson, Edwards, Taylor & Rankin, 1979) viewed this situation as

\textsuperscript{21} See Chapter 7 for an outline of classical test theory and factor analysis.
\textsuperscript{22} Miller (1976) reviews some of the earlier tests.
hampering the understanding of addiction to alcohol as none of these psychometric tests had any clear theoretical basis upon which they were constructed, viz., the alcohol dependence syndrome. To rectify this what they saw as an atheoretical approach to the assessment of alcoholism, these researchers constructed their own psychometric test which they argued to be conceptually founded on the alcohol dependence syndrome:

The development of the Severity of Alcohol Dependence Questionnaire (SADQ) was deemed necessary since to date, no such questionnaire has been devised which both stems from a clear recognition of a core syndrome of alcohol dependence and observes the crucial distinction between the essential features of the syndrome and the diverse consequences which may be associated with both dependent drinking and heavy non-dependent drinking (p.79).

Interestingly, the way in which Stockwell et al avoided the psychometric assessment of the “diverse consequences” mentioned above was to not follow the seven ‘dimensions’ of the alcohol dependence syndrome as laid down by Gross & Edwards (1976). Instead, these researchers argued that the seven dimensions clustered around a ‘drive’ to consume alcohol that was caused not by the elements of the dimensions, but by the perpetual avoidance and relief of withdrawal symptoms (à la Jellinek, 1960). Thus the SADQ comprised of five sections - physical withdrawal, affective withdrawal, withdrawal relief, typical daily consumption and the rapidity of the reinstatement of symptoms after a period of abstinence. Only the physical withdrawal and withdrawal relief sections of the SADQ faithfully represented the dimensions of the syndrome. The “abstinence” section in the SADQ pertained to the reinstatement of symptoms whilst the “abstinence” dimension in the syndrome pertained to the reinstatement of drinking. The remaining two sections in the SADQ were not original dimensions of the syndrome.

All items in each section contained a four point Likert type summated rating scale which numerically coded the frequency with which the respondent engaged in the behaviour contained in each item; the semantic categories of the scale being: ‘almost never’, ‘sometimes’, ‘often’ and ‘nearly always’. It was thought that such Likert scales would “cover a range of severity of symptomatology” (p.80). The SADQ was administered to 105 participants, all of whom were either hospitalised alcoholics or outpatients attending clinical services. In order to test the Gross/Edwards unidimensionality hypothesis, the data gathered were subjected to factor analysis. Four of the five sections (the alcohol intake section was left out of analyses) were subject to principal components analysis and items with the lowest loadings upon the principal component were discarded (Stockwell et al did not mention a loading ‘cut-off’ criterion here). Each section was then
subject to principal axes factor analysis so as “to determine whether one major factor would account for a majority of the variance to comply with the concept of a single syndrome of alcohol dependence” (p.82, original emphasis). One major factor was indeed found in each major section accounting for between 57 to 76% of the score variance. Then all items from all sections were submitted to another principal axes factor analysis which discovered a single factor accounting for 53% of the score variance. A Kaiser normalised oblique rotation retrieved the original single factors for each section. Stockwell et al concluded that the alcohol dependence syndrome was a unidimensional concept and the SADQ measured it:

...the Severity of Alcohol Dependence Questionnaire suggests that it is both a valid instrument and that it fulfils the requirements of the concept of alcohol dependence with respect to its internal structure (p.84).

Stockwell et al, however, did not publish all factor loadings and eigenvalues; a technical oversight which casts strong doubt over their findings. The poor amount of pooled item variance accounted for was another technical limitation. A good psychometric instrument should at least account for 70% of such variance (Kline, 1998) and conventional psychometric wisdom would claim that the 53% found in Stockwell, et al (1979) would be insufficient to demonstrate unidimensionality. Also, the post rotation retrieval of the section factors could have been an artefact of the presentation of the items in sections rather than the correlation matrix is being influenced by one single factor. With their re-engineering of the alcohol dependence syndrome, Stockwell et al did not make any reference to the concept of subjective control and emphasised that the core condition of the syndrome was psychobiological withdrawal symptoms.

Nevertheless, the Stockwell et al article influenced all further psychometric assessment of the alcohol dependence syndrome. Indeed, it became the most widely used diagnostic ‘screen’ questionnaire for the syndrome (Davidson, Bunting & Raistrick, 1989).

There was, however, one dissenting voice in the alcoholism literature. Chick (1980a & b) questioned the ever-perpetuated thesis of the unidimensionality of the alcohol dependence syndrome. Chick (1980b) even dared to question the usefulness of factor analysis in investigating the syndrome and proposed that the technique of Guttman scaling would be a better to test this property. Chick (1980a) had previously piloted and tested his own psychometric test, the Edinburgh Alcohol Dependence Schedule (EADS) so that its constituent items directly pertained to the seven clusters of elements of the
alcohol dependence syndrome. Chick (1980b) administered the EADS to 109 self-referred alcoholics at the Royal Edinburgh Hospital and then subjected the data to both factor analysis and Guttman scaling. A principal components factor analysis with an oblique rotation yielded seven factors with eigenvalues greater than one, but importantly, the factor solution did not follow the clusters of the alcohol dependence syndrome. Factor one pertained to withdrawal symptoms and relief/avoidance of symptoms by drinking; factor three by the Narrowing of Repertoire cluster; factor four by severe withdrawal symptoms (hallucinations and fits); factor five the Salience cluster and factor six the Increased Tolerance to Alcohol cluster (factor seven was not discussed).

Interestingly, the items pertaining to 'impaired control' ('can't keep to limit' and 'difficult to avoid getting drunk') loaded highly onto their own factor (factor two) and not onto a factor of Awareness of a Compulsion to Drink as predicted by the alcohol dependence syndrome. Indeed, this cluster did not appear in Chick's factor analysis at all. Interestingly, none of the items of the EADS formed Guttman scales. Chick concluded that his results cast doubt upon the hypothesised unidimensionality of the alcohol dependence syndrome. He even suggested that Gross & Edwards may have set up the theory to be unfalsifiable as results such as Chicks's could be explained away by either the participants withholding information or the researcher taking insufficient care. In regards to the concept of 'impaired control', Chick concluded that it did not belong in the grab-bag of the alcohol dependence syndrome and hinted that the concept may be worthy of investigation in its own right as a separate dimension. Edwards himself (1986, p.175) commented: "Chick's conjecture that 'loss of control' may not align with the other elements is exactly the sort of good question which one would hope to see emerge'.

Raistrick, Dunbar & Davidson (1983) argued that although the SADQ recognised the alcohol dependence syndrome, the psychometric test did not encompass the entirety of it. The SADQ was primarily concerned with the physical withdrawal symptoms of addiction to alcohol and therefore, according to Raistrick, et al, was no test of the unidimensionality of the syndrome. Physical withdrawal symptoms mostly pertain only to severely dependent drinkers and the SADQ, according to Raistrick et al, "... is sensitive only at the severe end of the dependence continuum and cannot therefore be said to measure the range of dependence and so is of limited usefulness as a measuring instrument" (p.89).

Thus Raistrick et al proposed the Alcohol Dependence Data (ADD) questionnaire. This questionnaire was composed of 39 items with semantic contents designed to assess
individual drinkers across a range of dependence to alcohol. Items pertained to obsessive thoughts about drinking, subjective control, attempts at giving up in addition to physical withdrawal symptoms and hallucinations. Laudably, these researchers submitted the questionnaire to a pilot study which administered the ADD to a heterogeneous subject sample of alcoholics, regular drinkers and psychiatric patients (although not those suffering psychoses or organic conditions). Next to each item were four dashed lines organised into columns by the semantic categories of ‘never’, ‘sometimes’, ‘often’, and ‘nearly always’, which were scored 0, 1, 2, and 3 respectively. By excluding items that had a Pearson’s product–moment correlation value of less than .60 with the total item score (a procedure known as item analysis (Kline, 1998)), and by keeping only those items whose score distributions approximated a normal curve, a 15 item version called the Short – form Alcohol Dependence Data questionnaire (SADD) was proposed. Not willing to subject the data to factor analyses, Raistrick et al found a Spearman split-half correlation between odd and even numbered questions yielded a satisfactory value of .87. Raistrick et al concluded that a factorial analysis of the SADD would be needed to test the unidimensionality hypothesis.

This they later did. Davidson, Bunting & Raistrick (1989) recruited self–referred alcoholics from three different UK hospitals. All were administered the SADD and the data from the three groups subjected to different analyses. In order to “... assess the structure of the items in terms of a unidimensional measure of alcohol dependence” (pp.911-912), the data of the first group received a principal axes factor analysis without rotation. A single factor emerged that accounted for 44% of item score variance with all items bar one loading above .5. This poorly loading item was then withdrawn from further analyses. Interestingly, this item pertained to subjective control and read: “Do you try to control your drinking by giving it up completely for days and weeks at a time?”. Another analysis was conducted and two factors emerged with the first factor now accounting for 49% of item score variance. Davidson et al did not publish the variance accounted for by the second factor and simply proceeded to subject the data to confirmatory factor analysis, hypothesising a two-factor simple structure solution.

For all three groups such a solution emerged, however, most items loaded weakly onto the second factor with one or two items loading inconsistently above the conventionally accepted value of .3. All items loaded very strongly onto the first factor and accounted for 47%, 32% and 47% of the item score variance in the three groups respectively. Davidson et al concluded:
These results indicate that the SADD is a unidimensional scale and would add to the existing evidence pointing to the homogeneity of the alcohol dependence syndrome (p.914).

If the evidence of their study supports the homogeneity of the syndrome, however, then why did the subjective control item fail to load onto any factor despite its inclusion in the alcohol dependence syndrome? This finding of Davidson et al added further evidence to the findings of Skinner & Allen (1982) and Chick (1980b) that subjective control is independent of the alcohol dependence syndrome. The technical limitation of the factors accounting for a low amount of item score variance renders the conclusion of unidimensionality of the SADD problematic.

A less critical paper appeared shortly before Raistrick et al (1983) yet it sought to incorporate all the features of the alcohol dependence syndrome into a psychometric instrument as Raistrick et al attempted. Although acknowledging the criticisms of Shaw (1979), Skinner & Allen (1982) developed their Alcohol Dependence Scale (ADS) with the aim of “... the measurement and validation of the alcohol dependence syndrome” (p.200). Skinner & Allen proposed that their scale encompassed the major clusters of the alcohol dependence syndrome, in that items pertaining to ‘loss of control’, severe withdrawal symptoms (physical and perceptual) and obsessive-compulsive drinking were written. Skinner & Allen administered their test to 225 alcoholics self-referred for treatment. A principal axes factor analysis yielded a one factor “simple structure”, the total variance accounted for by this factor being only 31%. Both orthogonal and oblique rotations failed to produce the factors predicted by the alcohol dependence syndrome. Varimax orthogonal and indirect oblimin oblique rotations produced three factors. Two were labelled ‘alcohol withdrawal symptoms’ and ‘obsession – compulsion’. Replicating the finding of Chick (1980b), the ‘loss of control’ items loaded onto their own factor; adding evidence to the argument that subjective control is separate to the alcohol dependence syndrome. This factor, however, and the ‘obsession-compulsion’ factor accounted for only 5.7% and 7.1% of the variance in ADS scores, respectively. Despite the great technical limitation of a poor amount of shared variance accounted for by the simple structure, Skinner & Allen not only concluded that: “... the alcohol dependence items form a predominantly unidimensional scale” (p.202); but that the factor analysis had indeed discovered that the alcohol dependence syndrome was an additively structured psychological attribute:

A second advantage of the Alcohol Dependence Scale is that it may be used to order individuals along a continuum of alcohol dependence rather than make a discrete diagnosis.
of alcoholic or non alcoholic. The finding in this clinical sample that the Alcohol Dependence Scale scores conformed quite closely to a normal distribution provides empirical support for a quantitative interpretation of the syndrome as existing in degrees of severity (p.206).

4.7 The first independent psychometric investigation of “impaired control” in alcoholism research

Subjective control, however, languished within the alcohol dependence syndrome for more than a decade after Chick (1980a) first raised his concerns about its inclusion in the ADS. It was not until the early 1990s that researchers in the field of alcohol addiction decided that the attribute was worthy of investigation in its own right. Heather, Tebbutt, Mattick & Zamir (1993) were the first researchers to attempt to assess psychometrically subjective control as an independent psychological attribute.

Heather et al recognised the problems and findings of previous psychometric research conducted a decade before hand. Subjective control had been hard to assess accurately and Heather et al reasoned that it was due in no small part to the question of its being either quantitative or non-quantitative: “... there are also problems concerning whether impaired control should be seen as dichotomous and whether or not impaired control is confined to ‘alcoholics’”(p.701). The previous experimental research of the Sobells and others, Heather et al argued:

... suggests the need to conceptualise problems with control as a continuous variable reflecting the frequency with which episodes of impaired control occur rather than existing in an “all or none” fashion, and this is the main advantage of speaking of impaired control rather than loss of control. It is also, of course, in keeping with modern conceptions of alcohol dependence (p.701).

Given their pains, however, to identify the limitations of ‘loss of control’, it is interesting that Heather et al persisted with the Edwards / Gross idea of ‘impaired control’. Of course, politically it was in keeping with the alcohol dependence syndrome, as evidenced above, but Heather et al were making a strong attempt to argue that individuals who drink differ in how able they are to control their drinking. One can legitimately presume therefore that most individuals can exercise such volitional control over their drinking that they never have to think about controlling their drinking at all. It then seems that these individuals do not possess an attribute of ‘impaired control’ as their volitional ability to control their drinking is not impaired in any way. Hence it is illogical to conceptualise subjective control as ‘impaired control’ given the obvious fact that many non-addict drinkers do not have an impaired capacity to moderate their intake. The use of
the term ‘subjective control’ avoids this confusion as it can cover the behaviours of those drinkers whose subjective control is either total, impaired, ‘lost’ or anywhere in between.

All the items of the Impaired Control Scale (ICS) of Heather et al were structured in such a way as to be asking the respondent to recall a certain behaviour and then to use the Likert type rating method under each item to indicate an approximate frequency of the said behaviour. Similarly to procedure of Skinner & Allen (1982), they classed the items into three groups. The first group contained items pertaining to attempts at: limiting the amount of alcohol drunk; resisting urges to start drinking; ceasing drinking behaviour completely for some period of time; slowing drinking; and cutting back on drinking. The aim of this group of items was to discriminate between drinkers who attempted to control their behaviour and those who did not (Heather et al, 1993). This was done as it was hypothesised that it would be otherwise difficult to differentiate between light drinkers who never felt a subjective need to control their drinking and those heavy problem drinkers who had abandoned attempts to control their drinking. The second group consisted of 18 items that pertained to failures at attempts to control drinking, such as: “During the last six months, even when I intended having only one or two drinks, I ended up having many more”. Both these groups began each statement with the predicate “during the last six months” so respondents could have a time frame with which to assess the frequencies of the behaviours proposed by the items. The third group of 18 items attempted to assess respondents’ own personal beliefs about their control over their gambling behaviour. The semantic content of the items of groups 2 and 3 were similar but were phrased differently, items of group 3 not having the initial predicate of those in group 2.

Heather et al submitted this preliminary ICS to a pilot test. After a principal components factor analysis was performed (argued as a check of the validity of the three part structure), all items were submitted to item-total correlation tests. The ICS was redrafted so as to keep the three part structure with part one now consisting of five items and parts two and three ten items each. This version of the ICS was then administered to 128 problem drinkers undergoing clinical therapy. The data was submitted to another principal components factor analysis without rotation, which found one factor accounting for 31.9% of pooled item score variance, with items from parts two and three loading above .4 on this factor. Part one items loaded poorly on this factor and loaded highly onto another which accounted for 15.1% of pooled item score variance. A Direct Oblimin oblique rotation was performed which uncovered three factors for each questionnaire
section, but Heather et al did not publish the loadings or accounted variance of the
rotated factor solution.

Interestingly, Heather et al had also administered the SADD to their subjects because
"... it provides the most complete coverage of the elements of the alcohol dependence
syndrome" (p.706). Heather at al combined the data from the SADD and the ICS and
submitted it to another principal components factor analysis with an oblique rotation. The
factor which all ten of the part two ICS items loaded onto heavily was also the factor
which the two subjective control items in the SADD loaded. Only two others of the
SADD’s 15 items loaded onto this factor, the rest loading heavily onto another. This
again adds evidence to the argument that subjective control is an attribute independent of
the alcohol dependence syndrome. Heather et al concluded that "... evidence has been
presented here to suggest that it is possible to measure impaired control over alcohol
consumption in a reliable and valid fashion" (p.707) and that all items "...were found to
contribute to a single dimension of impaired control." Yet again, however, Heather et al
did not publish either the factor loadings nor accounted variance of the factor structure.
As with other psychometric research into the alcohol dependence syndrome, the variance
accounted by the initial factor analysis of the ICS was of an insufficient magnitude to
support the hypothesis of unidimensionality.

Nevertheless, the Heather et al study remains the most recent attempt to assess
psychometrically the attribute of subjective control within the field of addiction to
structural equation modelling and the allied technique of confirmatory factor analysis.
They found that the simple structure solution consisted of three factors which they
labelled 'Attempted control', 'Failed control' and 'Predicted control'. This was not
consistent with the single factor solution discovered by Heather et al (1993). Like
Heather et al, Marsh et al did not report the amount of item score variance accounted for
by the factorial solution. Hence at this stage, nothing conclusive about the internal
structure of the ICS can be logically ascertained.

4.8 The influence both of medicine and alcoholism research upon research into
problem gambling

The incorporation of the attribute of subjective control in the literature on problem
gambling has been one of simple adoption. The gambling researcher Dickerson
(Dickerson, Cunningham, England & Hinchy, 1991) and his associates (Baron,
Dickerson & Blaszczynski, 1995; Dickerson & Baron, 2000; Shepherd & Dickerson,
2001) have been the main protagonists of research into problem gambling following the research processes undertaken in the area of addiction to alcohol. Dickerson et al (1991) proclaimed that the benefit in so doing would be to conceive ‘loss of control’ in gambling as the continuous and quantitative psychological attribute of subjective control that had lately emerged in alcohol research (viz., Heather et al, 1993):

If in this domain of research into addictive behaviour we indeed are going to take advantage of the hard won lessons of the literature on alcoholism (Dickerson, 1987), then it seems preferable to assume that there is a continuum of level of involvement in gambling, at least until substantive evidence to the contrary has been found.

Like the study of addiction to alcohol, addictive gambling behaviour research has been influenced enormously by the discipline of medicine. The dominant medical view of addictive or problem gambling is that it is a ‘pathological’ mental disease. The Australian Psychological Society recently published a position paper (Blaszczynski, Walker, Sagris & Dickerson, 1999, p.11) which succinctly expressed the limitations of the medical view:

The disease model suggests that problem gamblers are categorically distinct in some way from social gamblers and non-gamblers. This view is espoused by Gamblers Anonymous and clinicians who advocate gambling as an addictive disorder. The opposing dimensional view argues that gambling lies on a continuum with arbitrary cut-off points delineating persons who could heuristically be labelled social, regular, heavy and problem gamblers...... To date there is no evidence that provides a strong argument in favour of the categorical disease model....There are no consistent personality differences or characteristic patterns of behaviour separating subgroups of gamblers from one-another, except that problem gamblers spend more time and money gambling and therefore experience more difficulties.

Shortly after the World Health Organisation’s acceptance of the alcohol dependence syndrome, the first attempt to medicalise problem gambling was in the publication of the Diagnostic and Statistical Manual of Mental Disorders, Third Edition (DSM – III) of the American Psychiatric Association (APA, 1980). The APA focussed initially on the behaviour’s perceived criminality, with diagnostic criteria for ‘pathological’ gambling being “arrest for forgery, fraud, embezzlement, or income tax evasion due to attempts to obtain money for gambling” and “borrowing money from illegal sources (loan sharks)” (p.293). Only much later, when the alcohol dependence syndrome became the theoretical core of all research into addiction to alcohol, was the APA to discard these less than satisfactory criteria in the DSM III – R (APA, 1987) and DSM – IV+ (APA, 1994) in favour of listing the psychological and social phenomena observed to be associated with problem gambling. These included heightened arousal, the persistent pursuit of losses,
obsessive thoughts regarding gambling, unsuccessful attempts to control gambling behaviour and use of gambling as a panacea for depression.

The latest edition of the DSM, the DSM – IV+ (APA, 1994) classifies problem gambling as an impulse-control disorder and posits that the essential feature of it is "...the persistent and recurrent maladaptive gambling behaviour (Criterion A) that disrupts personal, family, or vocational pursuits" (p.615)\textsuperscript{23}. Displaying the influence of Jellinek’s (1960) research on alcoholism, the DSM states:

Most individuals with Pathological Gambling say that they are seeking "action" (an aroused, euphoric state) even more than money. Increasingly larger bets, or greater risks, maybe needed to continue to produce the desired level of excitement (p.616).

Hence the DSM is arguing that the ‘loss of control’ a problem gambler displays is caused by the need to experience the psychological sensation of euphoria; and like tolerance to alcohol in the alcoholic, a need arises to increase gambling activity in order to achieve the desired sensation of increased intensity. Importantly, the DSM did not attempt to argue for causal mechanisms of the behaviour. It proposes, as for the alcohol dependence syndrome, clusters of behaviours and associated social phenomena of which a minimum number need to be present in order for the condition to be diagnosed and thus treated. The professional interests of medicine influenced gambling research as much as they did alcohol research.

Medicine’s conceptions of problem gambling, however, did not escape criticism. Blaszczynski & McConaghy (1989) pointed out that the diagnostic criteria in the original DSM III (APA, 1980) classification had been constructed using the data obtained from interviews with problem gamblers attending Gamblers Anonymous (GA). Like its model organisation, Alcoholics Anonymous, GA is a self-help group which has a political adherence to the disease concept of addiction, which argues that problem gambling is an irreversible, incurable disease. Although later editions of the DSM moved beyond studies with such biased participant samples, the diagnostic criteria were still limited by heavy reliance of data collected retrospectively from self-referred problem gamblers. It has been found that such information is unreliable on its own and cannot be extended to the population of problem gamblers (Baron, Dickerson & Blaszczynski, 1995).

Both Wakefield (1997) and Dickerson & Baron (2000) argue that the most problematic features of the DSM IV criteria are the over-inclusiveness of the criteria and

\textsuperscript{23} The International Classification of Diseases, Ninth Revision (Commission on Professional and Hospital Activities, 1986, 1991) tables the DSM taxonomy of pathological gambling under Mental Disorders.
their heterogeneity. These flaws have had two separate consequences. One has been the clinical assessment problem of false-positive diagnoses (Baron & Dickerson, 2000). Given the legal and medical status the DSM enjoys in Western nations, false-positive diagnoses can entail serious legal implications. The other consequence of the DSM criteria is they do not logically constitute either necessary or sufficient conditions for the diagnosis of ‘pathological’ gambling:

For example preoccupation with, and an increasing need for an activity, and desires/attempt
to reduce or stop that activity do not logically imply a mental disorder. Criteria 5, gambling
as a way of escaping from problems or relieving a dysphoric mood could equally be true of
any leisure activity such as going to a football game or the cinema, and in some cases could
conceivably be as expensive (e.g. sailing) (Dickerson & Baron, 2000, p.6)

Dickerson & Baron argue that the heterogeneity (and perhaps irrelevance) of the DSM IV criteria has hampered the elucidation of exactly which variables cause ‘pathological’ gambling and the degree of independence these variables have from other potentially influential variables.

Nevertheless, the status of ‘pathological gambling’ remains unchanged. As for the alcohol dependence syndrome, the APA’s classification provided the bases for the psychometric assessment of problem gambling (Lesieur & Blume, 1987). The pertinent psychometric test proposed was the South Oaks Gambling Screen (SOGS) (Lesieur & Blume, 1987) and it, like the SADQ instrument of Stockwell et al (1979), became not only the definitive (and legally recognised) instrument in diagnosis, but also has been at the core of epidemiological studies of prevalence (see Gambino, 1997). An unnamed factor – analytic scale for the measurement of ‘pathological’ gambling was proposed by Zimmerman, Meeland & Krug (1985) but did not receive serious attention.

Lesieur & Blume (1987) did not follow the precedent of using factor analysis in the alcoholism literature in the development of their scale. The alternative test of validity, these researchers argued, was the independent judgments made by gambling counsellors of clients according to the criteria set out in the DSM – III (APA, 1980). Although assuming pathological gambling to be quantitative, Lesieur & Blume (1987) did not state that it was unidimensional. Nevertheless, very similarly to the view of the alcohol dependence syndrome (Edwards & Gross, 1976), Lesieur & Blume’s interpretation of the DSM – III criteria rendered a clustering of gambling – associated social and psychological phenomena around seven distinctive themes. These were:

1) family disruption, 2) job disruption, 3) lying about wins and losses, 4) default on debts, 5)
going to someone to relieve a desperate financial situation produced by gambling, 6)
borrowing from illegal sources, and 7) committing an illegal act to finance gambling (p.1185).

Despite no explicit statement as such, the clusterings were designed, as in the alcohol dependence syndrome, to be roughly ordered according to the severity of symptoms experienced. This was evidenced in the structure of SOGS and how participants’ responses were scored. Likert (1932) type ratings scales were not used and instead, nine of the 12 items scored in the SOGS (out of a total of 15) had a dichotomous yes/no response design. The three remaining items had response categories designed to assess the frequency with which the participant engaged in the said behaviour; and responses to certain categories for these items together with the ‘yes’ responses to the other items were simply tallied to obtain an aggregate score. No matter exactly which items the participant responded to, if that participant’s tally exceeded five, then the participant was a “probable problem gambler” (Lesieur & Blume, 1987,p.1188). This cut-off aggregate of responses, however, is not culturally independent. A modified version of the SOGS designed for use in Australia has a cut – off score of 10 (Blaszczynski, McConaghy & Frankova, 1991). The cut-off score is an arbitrary value and has little use beyond medical diagnosis.

Similarly to its fate in the alcohol dependence syndrome, subjective control in Pathological Gambling was subsumed within the DSM (APA, 1980, 1987, 1994) criteria. Its structure and role in gambling addiction was not thought worthy of psychometric investigation in its own right. Within the SOGS, it received an operational definition as ‘chasing’ behaviour, which is an incident of persistent gambling during losses with the intent being the reclamation of those losses.

4.9 The first psychometric investigation of ‘subjective control’ in the area of gambling behaviour

The assessment of subjective control as an attribute acting independently upon gambling behaviour follows from the theoretical orientation of Dickerson and his colleagues:

It is suggested that an alternative approach focussing on the construct of choice or subjective control over gambling may be a research direction that will ensure that progress is maintained (Dickerson & Baron, 2000, p.1)

The first attempt to assess psychometrically subjective control in gambling behaviour as an attribute independent of a medical disorder was the study of Baron, Dickerson &
Blaszczynski, (1995). Baron et al deliberately selected the study of Heather et al (1993) as the model for their own, and even structured the final version of their psychometric instrument, the Scale of Gambling Choices (SGC) almost identically to the ICS. Criticising the SOGS (Lesieur & Bloom, 1987) for its “variegated composition” (p.155) (i.e. the heterogeneity of the items), Baron et al (1995) laudably recognised that psychometric apparatus developed thus far in the addictions literature often confused potentially causal attributes with symptomatic effects. Despite the various explanations posited for addictions generally, these researchers argued that subjective control was a component common to them all; and hence that the investigation of subjective control has:

... the potential to generate significant research development in the understanding of the psychological processes that may underlie addictive behaviours such as problematic gambling (p.155).

Following, however, the example set in the alcoholism literature, Baron et al assumed that subjective control was a continuous and quantitative psychological attribute. This was done for two reasons. Quantitative attributes are measurable and so hence a logical attempt can be made to devise a measurement apparatus. Secondly, that a quantitative attribute of subjective control would better suit the purposes of medical treatment in avoiding the problems of false negative and positive diagnoses of pathological gambling associated with the SOGS’s arbitrary ‘cut-off’ tally design. Following the modus operandi set down in alcoholism research, the multivariate statistical procedure of factor analysis was used by Baron et al to achieve the above ends.

Initially drafted were a set of 18 items that were argued to pertain to the manifested gambling behaviours of impaired subjective control. These behaviours were:

- Chasing (a subjective experience of an increased urge to bet following a losing sequence).
- the desire to limit or stop gambling (and the reported difficulty of attaining these objectives); and spending more than intended (in terms of time and money) (pp.155-156).

Item response methodology adopted the Likert (1932) design of summed ratings, with the categories of ‘never’, ‘rarely’, ‘sometimes’, ‘often’ and ‘always’ scored 1, 2, 3, 4, and 5, respectively. As in the ICS (Heather et al, 1993), this methodology was employed to assess the frequency with which the respondent engaged in the behaviour contained in the predicates of each item.

Baron et al used the statistically laudable sampling design of a random, stratified door knock across the four major Australian cities of Sydney, Melbourne, Brisbane and Adelaide. Two hundred and eighty seven participants were recruited in this way and all
were administered the SGC. Additionally, 100 gamblers classified as pathological according to the problematic DSM – III (APA, 1980) criteria were administered the scale. A principal axes factor analysis was then undertaken with a Varimax orthogonal rotation for both sets of data. The results were not interpretable for either group. The data of the door knock sample fitted a three-factor simple structure solution which was problematic given the heavy cross-loading of some items and the great range of communalities across the items (.23 to .82). Similar results were obtained from the pathological gambler sample, except the cross – loading of items was worse. The use of factor analysis on this latter sample did, however, suffer the technical limitation of a low participant to item ratio of 5.56:1 (Kline, 1998).

In order to clarify the factorial structure of the SGC, Baron et al. (1995) made use of the technique of item clusters, whereby items of similar expression and semantic contents are presented together in groups. The SGC was revised so as to consist of two such clusters. Part one consisted of six items that pertained to actual attempts to control or limit gambling behaviour within a time frame of the previous six months. Part two consisted of 12 items designed to assess failures of control over gambling within the same time frame. A random, stratified sampling procedure was undertaken in both Western Australia and Tasmania; and this time sampling was not limited to the metropolitan areas of these states. The samples consisted of 204 and 295 people respectively, and factor analyses were conducted separately on responses from each.

The item clustering technique yielded for both samples three - factor simple structures with high communalities across all items and negligible cross loadings. Both oblique and orthogonal (Varimax) rotations produced solutions with negligible differences, thus finding that the factors were uncorrelated. Baron et al. labelled these three factors as “‘ability to control gambling’; ‘intentions to limit gambling’; and ‘failure to control gambling’ ” (p.164). The total item score variance accounted for by this factor solution in the Western Australian and Tasmanian samples were, respectively, 61.7% and 64.6%. Correlations between the item totals of the SGC and the SOGS were conducted for both samples as a method of establishing criterion validity. Large and statistically significant correlations were found ($r = .87, p < .001$; $r = .92, p < .001$).

Due to the multifactorial structure, Baron et al. did not conclude the attribute of subjective control to be unidimensional, however, they did consider their results as supporting subjective control as a measurable, and hence quantitative, psychological attribute. Quite in contrast to alcoholism researchers, Baron et al. were critical of their
own findings; and posited that the simple structure solutions obtained may have been due only to the method of presenting the items (viz., item clustering). Baron et al concluded that while subjective control remained a "...crucial factor to measure" (p.166), further development of a suitable psychometric apparatus remained to be conducted.

4.10 Criticism of the dispositional trait concept of subjective control

The various conceptions of subjective control hitherto proposed by the alcoholism and gambling researchers suffer from two theoretical inadequacies which render the conceptions problematic. These inadequacies may at first glance appear to be separate, but it will be demonstrated that one is really an invalid argument synthesised from the premises and conclusion of the other.

The first inadequacy is that the structure of subjective control has never actually been hypothesised as a scientific attribute (ie a class of mutually exclusive properties or relations). At the hands of researchers both in alcoholism and gambling, subjective control, since the discrediting of Jellinek's (1960) disease theory of alcoholism, has been reified as a disposition to produce certain effects. This tendency to make dispositional trait arguments in the area of addiction was noted by Babor (1986) in a highly critical commentary upon Edwards (1986):

First, the ADS [Alcohol Dependence Syndrome] is a dispositional concept, referring to a rather permanent property or condition of an individual which is manifested in a variety of circumstances, and is attributed to the individual even when not manifested. In many respects the ADS resembles the notion of habit or acquired trait in psychological theory, and as such carries much of the same theoretical baggage (p.185).

Various examples of this tendency were outlined in the above historiography. For instance, 'chasing' behaviour in gambling was argued by Dickerson et al (1991) as being poor subjective control. 'Chasing' behaviour occurs when a gambler persists at his or her gambling play despite either a previous sequence of lost gambles or a current sequence of losing gambles. An example of the former may occur when a gambler returns to a licensed venue one evening with the view to recommence Electronic Gaming Machine (EGM) gambling activity after sustaining a series of losses the previous evening. An example of the latter may occur within a session of EGM gambling where a sequence of losses results in an extended period of EGM play in the attempt to recoup those losses. According to Dickerson, both are examples of individuals displaying poor subjective control.
However non-trivial chasing behaviour may be, it is inadequate to define subjective control as instances and non-instances of chasing behaviour. It blurs the necessary distinction between cause and possible effect. It is possible that chasing is an effect of the behaviour of a hypothetical latent attribute of subjective control. Arguing, however, that an individual displays a low level of subjective control because that person has engaged in chasing behaviour given the argument that if there is low subjective control displayed then there exists chasing is incorrect as the consequence of the proposition has been asserted. In other words, the existence of a causal attribute cannot logically be obtained (yet it can be conjectured) simply through the observation of a possible effect of that attribute. It is most certainly a possibility that effects may be caused by an unknown attribute different to the one hypothesised (or conjectured) to be causal. This possibility is fatal to the dispositional concept.

The second inadequacy of previous conceptions of subjective control is that it has been hypothesised not only as a dispositional trait, but a quantitative one. Of course, this assumption of quantity flows via invalid argument from the dispositional concept (viz., the definition of an attribute as its effects). Many effects which have unknown causes that are psychological in origin are often quantitative. For example, both frequencies of correct responses made to an aggregate of mathematics questions and the time it took the respondent to complete each item are both quantities. The first is an aggregate magnitude and the second a magnitude of a known continuous quantity. If it is reasoned that all such effects are quantitative (and indeed they could be) and if the attribute is argued as being comprised of these effects, then the attribute must be quantitative. Such a conclusion is often taken as valid in psychology as the conclusion is logically entailed by the premises. It is, however, on empirical grounds rendered invalid with respect to both premises.

With respect to the first premise, not all effects of causes psychological in origin are quantitative. A response to an essay question is a non-quantitative effect of intelligence. It is usually taken as indicative of the individual’s grasp of a certain topic and is used as a form of assessment in many different academic fields. Secondly, an attribute may produce both quantitative and non-quantitative effects. For example, an exam on quantitative psychology may have both essays and a finite collection of multiple choice questions. Whilst the multiple choice format will readily yield an aggregate of correctly answered questions, it is far from clear whether the responses elicited by the essay questions are quantitative. Thirdly, it is quite a difficult process to tease out exactly which effects are caused by what attributes. This is especially so in psychology where
technologies of stimulus control are either in the process of development or non-existent. For example, the effects present in an exam on quantitative psychology may either result from a hypothetical attribute of 'ability to comprehend quantitative psychology' or from the more elementary processes of reasoning, short and long term memory (and their capacities), attention, writing ability, mathematical ability and motivation (Luce, 1995 notes this problem). To further obscure matters, it is possible that a confluence of these attributes contribute to the responses made to an exam paper. The argument that all psychological effects are quantitative cannot be seriously entertained until the above points have serious doubt cast upon them. This has yet to happen.

With respect to the second premise, it is quite often argued that quantitative effects logically entail quantitative causes given that the complexity of the cause must equal the complexity of the effect. This is a plausible argument but like such arguments it does not always hold empirically. It is logically possible that non-quantitative attributes can have quantitative effects and vice versa (Michell, 1999). For example, certain differing volumes of white paint may be added to a standard volume of red paint and non-quantitative effects result (ie changes in shades of red). Conversely, using an example given by Michell (1999), two computers may be presented with a problem in symbolic logic and take different amounts of time to solve it. The discrepancy in completion times is due to the difference in the programming of the computers (one uses a program based on Venn diagrams and the other axiomatised logic).

Secondly, the points raised with respect to the first premise pose serious problems for the second premise. For example, if the first premise is asserted as true (viz., a psychological attribute is the class of its effects) and there exists in this class both quantitative and non-quantitative elements, then it logically follows that the attribute is both at once qualitative and quantitative. This is, however, an invalid argument as it is impossible that any attribute is both quantitative and non-quantitative. Quantities and qualities may share the property of order but only quantities possess the structural feature of additivity; hence the two categories are mutually exclusive. In order to sustain the second premise (and to make the above argument valid), serious arguments supported by empirical evidence would have to be raised against the distinction between qualitative and quantitative structures. This also has yet to happen and is very unlikely.

As the falsity of the premises in any argument logically entails the falsity of the conclusion, it cannot be argued *via the concept of the dispositional trait* that psychological attributes are quantitative. As subjective control is currently defined as a
dispositional trait, the above conclusion logically extends to subjective control. Whatever quantitative effects the attribute of subjective control manifests in either alcohol or gambling addiction, it cannot be concluded that the attribute itself is quantitative. Of course, as the theory of additive conjoint measurement (Luce & Tukey, 1964) can test the order upon both quantitative and non-quantitative effects of attributes, the structure of the attributes themselves can be inferred, conjoint measurement can be used to test the structure of subjective control. This has yet to be done.

As was demonstrated in the historiography, the research into subjective control has not always conceptualised the attribute as being a dispositional, quantitative trait. Jellinek (1960) argued that loss of control was simply a psychological effect of the biological disease of alcoholism (ie a symptom). A medical researcher, Jellinek saw no necessity (beyond speculation) of conceptualising loss of control any further than stating that it was the key symptom that identified the disease of alcoholism. It was only when research discovered that many individuals addicted to the consumption of alcohol did not display this psychological symptom was loss of control rejected and replaced by the quantitative, dispositional trait theory of impaired control by Gross & Edwards (1976). This theory is still held true in alcoholism research (Heather et al, 1993).

In relation to gambling behaviour, Dickerson & Baron (2000) have defined subjective control as the gambler’s ability or capacity to consistently play within predetermined levels of involvement. This definition implies that subjective control is a latent attribute or trait, rather than as a disposition. If this is the case, then the attribute could possibly be tested for additive structure using the theory of conjoint measurement (Luce & Tukey, 1964). Dickerson & Baron (2000), however, do not propose to do this and instead assume that the attribute is quantitative. They argue that the levels of involvement are evidenced by the amount of time spent gambling and the amount of gambling expenditure. They do not argue, however, that such effects constitute the attribute of subjective control. To do so would be simply confusing a class of effects with their possible causal attribute. Some elements within the class of effects associated with gambling behaviour are undoubtedly quantitative, such as size of wager, gambling session duration and reaction times to presented gamble outcomes. It is impossible, however, to directly infer the structure of causal attributes from their effects alone. Some other elements may not be quantitative or have not been demonstrated to be so.

At first glance, the argument that subjective control is a latent attribute conflicts with current dispositional theories of subjective control proposed by alcohol addiction
researchers. This incongruity can be explained by the ideology of operationism (Stevens, 1951). Researchers into addictions, like their counterparts in other areas of the behavioural sciences, have deemed it necessary to operationalise their theoretical concepts. As argued in Chapter 2, operationism decries scientific hypotheses consisting of metaphysical presuppositions and argues that such hypotheses be made relative to some observable behaviour. With the emphasis on observed effects, dispositional trait theory can render an attribute’s operational definition as its theoretical basis. Thus the dispositional trait definition appears to conflict with the psychometric argument that subjective control is a latent quantitative attribute.

There is an argument, however, which circumvents this. If the first premise of the dispositional trait argument is extended to include psychometric test scores, scores on instruments hypothesised to measure subjective control can be argued to be effects of subjective control. Hence, as Boring (1945) argued with intelligence, subjective control can be given a dispositional, operational definition as scores on a test of subjective control. Given that these scores can be aggregate quantities (such as yes/no responses) and, in the parlance of psychometrics, observed scores, then the fundamental proposition of classical test theory is satisfied; and given an estimated error term statistically calculated from the observed scores, the latent ‘true’ score can be identified. Thus the apparent disparity between subjective control as a dispositional trait and as a latent, psychometric attribute dissolves.

There cannot be any progress, however, in understanding subjective control if theoretical arguments of the phenomenon are still made in the form of the dispositional trait. What is needed is a general theoretical model of subjective control that can explain the effected behaviours that occur in both the substantive areas of alcohol and gambling addiction, rather than continue to argue different quantitative, dispositional theories of subjective control based on the attribute’s differing behavioural effects between the substantive areas. Such a theoretical model would allow for a distinction between cause and effect and could facilitate a test of subjective control for additive structure. It may also provide a more coherent account of the causal psychological variables involved in the non-trivial psychological and physical state known as addiction.

This is not to say that there have been no attempts to propose theories of subjective control in addiction that do not make dispositional arguments. Two notable examples are those given by D.A Wilkinson (1991) and J. Orford (1985, 2000). With modification,
these theories may provide a tractable basis upon which to build a non-dispositional theory of subjective control.

4.11 Wilkinson’s behavioural definition of subjective control

Wilkinson asserts the classical Cartesian argument that the self is the undeniable psychological attribute of conscious human existence:

Clearly self-control is an attribute of the self. As Descartes and the existential philosophers have indicated, the self is undeniably an attribute of consciousness; so, to understand self-control one needs to understand the place of consciousness in an objective neurophysiological science (1991, p.108).

The argument presented here is that as control pertains to the self of consciousness and no other part of consciousness, therefore it must be an attribute of the self. Wilkinson is assuming in his argument that subjective control is a property of the self. He does not hypothesise that subjective control might be an attribute of consciousness external to the self that enters into a relation with the self. He also avoids making any arguments concerning which aspects of the self exhibit control as he states:

Also, in defining self-control, one must try to delineate those aspects of the ‘self’ that exhibit ‘control’ (as in self-control), and describe the boundary conditions for their separation from the ‘other-controlled’ aspects of the self, if such exist. It can be argued on phenomenological grounds that such entities exist in certain perceptual experiences and emotional responses that are caused by external stimuli (p.108).

The purpose of this argument, it appears, is to allow for a general definition of subjective control, which Wilkinson gives:

Self-control, as the term is used here, can be somewhat more specifically defined as the ‘conscious inhibition of an otherwise predictable proximal response in anticipation of adverse distal consequences of the response (p.108).

This theory of subjective control as it stands is unsatisfactory. It defines subjective control only in terms of the conscious act of inhibition, as it argues that individuals must make the conscious effort to inhibit all responses that may have negative or injurious consequences. It does not account for the obvious fact that the self does not need to exert a conscious inhibition of its responses to all stimuli in the environment. For example, most individuals upon perception of a motor vehicle do not need to exert conscious inhibition of the self vandalising or stealing that motor vehicle. It is very probable that the thought of vandalising or stealing a motor vehicle does not enter into the conscious self even without the current perception of a motor vehicle. An argument from cognitive psychology states that humans have a limited attentional capacity. The conscious
inhibition of a response in order to avoid a consequence of that response which adversely affects the self requires a demand upon limited attentional resources. It is logically possible in Wilkinson’s argument that there could be an infinite number of stimuli in the environment that the self would have to consciously inhibit making responses to. For the self to be aware of all of an infinite number of stimuli the self would have to possess infinite attentional resources. Empirical research in cognitive psychology has found no evidence to suggest that the self possesses limitless attentional resources. Indeed, it has found that attention is quite limited and this limitation easily reached with the presentation of only few stimuli. Therefore, conscious inhibition as a sufficient condition of subjective control is untenable.

Wilkinson was attempting to extend his definition to include the addictions as evidenced by the phrase ‘adverse distal consequences’. This phrase is so general in meaning as to be almost useless. Crossing the street may have the distal consequence of getting hit by a truck but it is highly unlikely that an individual crossing a street has failed to consciously inhibit the self from walking across the street. The individual may get hit by a truck for a variety of reasons (eg a wish to commit suicide or poor visibility). Reference to addictive behaviours cannot be made in terms of the adverse consequences of addiction as many behaviours not historically identified as addictions have adverse consequences. A remedy for Wilkinson’s theory is to actually follow Wilkinson’s advice and elucidate exactly which components of the self are necessary for the self to exert conscious inhibition over. This said elucidation was achieved by Orford (1985, 2001).


Orford (2001, p.1) argued that a special class of behaviours exists which individuals often engage in to the extent that the state of addiction occurs:

There exists a range of objects and activities which are particularly risky for humans, who are liable to develop such strong attachments to them that they then find their ability to moderate their behaviour significantly diminished.

Orford argued that historical evidence suggested this class consisted of the behaviours of drinking alcohol, the ingestion of ‘hard’ and ‘recreational’ drugs as well as prescription medicines, eating, various kinds of gambling and sexual activity:

The total set is not adequately denoted as ‘drugs’ or ‘substances’, but is more correctly spoken of as appetitive activities which can become excessive (p. 342, original emphasis).

The facility of the behaviours present in this set to invoke innate pleasure and intense desire led Orford to term them appetites. He used this term for three reasons. Firstly, as a
basis for a general psychological understanding of addiction. Note that two members of this set, gambling and sexual activity, do not have as either a necessary or sufficient causal condition the introduction of psychoactive substances into the central nervous system. Gambling (Anderson & Brown, 1984) and sexual activity (Barlow & Durand, 1995), however, have both been found to create very high levels of pleasurable, physical arousal. Thus gambling and sexual activity are appetitive and so hence are potentially addictive (Blaszczynski, Walker, Sagris & Dickerson, 1999).

Secondly, the field of addiction research has moved towards models in which addictive behaviours are intrinsically very pleasurable. During the past 20 years it has moved away from models (such as Jellinek’s (1960) model of alcoholism) in which negative reinforcement, escape/avoidance and deficit reduction are argued to be the primary mechanisms of addiction (Orford, 2001). They are now argued to be secondary mechanisms and may be involved when subjective control over the appetite is overcome (Orford, 2001). The intrinsic pleasure the appetitive behaviours appear to have suggests that certain electrochemical processes in the human brain play a major role independently of time and culture. As a consequence, research has been conducted in this area and it was first thought that the dopaminergic neurotransmitter system was heavily involved (Orford, 2001). More recent research strongly suggests that the serotonergic neurotransmitter system is also involved in addiction to alcohol (Ciccocioppo, 1999; Kampov-Polevoy, Garbutt & Janowsky, 1999). This field of research, however, is in its early stages and as yet has produced nothing conclusive.

Thirdly, Orford used the term to include what he argued to be the important sphere of social influence that surrounds the engagement of appetitive behaviours. Orford argued that the appetites, in and of themselves, cannot be termed excessive without respect to the cultural norms and rules which attempt to regulate the appetitive behaviours. Orford noted that almost all human adults find at least one of these appetitive behaviours pleasurable and engage in them regularly at non-problematic levels. When relative to these norms and rules, an individual’s appetite becomes excessive and creates harm, the culture within which that individual exists often declares that the individual possesses an addiction.

How, then, does an appetite become excessive? Orford argued that: “... the repeated experience with an appetitive activity can produce changes that increase the attraction that activity holds for a person” (1985, p.207). This repeated experience can lead to an individual developing a strong psychological attachment to the appetitive behaviour.
Attachment primarily consists of three components. Firstly, a strong emotional attachment to the appetitive behaviour. It has been noted in gambling research that gambling activity has for many individuals a strong mood altering capacity. Secondly, the intention to engage with the appetitive behaviour. Thirdly, a ‘cognitive commitment’ (p.207) to the appetite and the manner in which the individual engages the appetite. Orford states:

The development of a strong appetite can be attributed to the relative weight of incentives for appetitive behaviour, or functions served by it, over the disincentives or restraints operating at each stage, plus the increasingly influential increment in attraction brought about by the powerful and complex learning and cognitive processes...helped on by biological changes in the case of some drugs (p.207).

Orford argued here that an addiction results when ‘discentives or restraints’ are overcome by the attachment of the individual to the appetitive activity. The psychological mechanism by which the restraints against appetitive activity are overcome is approach – avoidance conflict (Heilzer, 1964; cited in Orford, 1985). Orford stated that incentives and disincentives towards appetitive behaviour take the form of internal and external cues. For example, an external incentive towards gambling may be the atmosphere of a casino whilst a restraining cue may be the memory of losing hundreds of dollars the week before. If an individual addicted to gambling is distant from engagement in gambling activity, the disincentives will be stronger and thus the individual will avoid the engagement. The closer the individual moves towards engaging in appetitive behaviour, the incentive cues become stronger. After an equilibrium point is reached where both incentives and disincentives neutralise one another, the incentives become stronger and thus lead the individual to engage the appetitive activity.

Orford stated that ‘loss of control’ is merely an experiential phenomenon caused by the addicted individual’s approach-avoidance conflict. Indeed it could be. Jellinek’s (1960) thesis posited that ‘loss of control’ over drinking was the rapid ingestion of successive drinks after the ingestion of one initial beverage. Here internal disincentive cues to drink are overcome by the strong external incentive cue of the ingestion of an alcoholic beverage which then causes an excessive engagement with drinking behaviour. The rapid, excessive engagement leads the individual to feel that he or she has ‘lost control’.

The major flaw in this argument is its insinuation that the engagement with an appetitive behaviour is the sum of psychological incentives and disincentives. It seems to
imply that individuals who engage in appetitive behaviours do so only after consciously weighing the advantages and disadvantages of the engagement. This is unlikely to happen to all individuals who enjoy drinking, gambling or narcotics. Only those who are strongly attached or addicted to these behaviours may reflect about the consequences of their actions, but to argue that this reflection is always a causal restraint operating against other strong incentive cues is mere speculation. Many problem drinkers and gamblers sometimes think about the consequences of their actions but it is obvious that such thoughts rarely stop excessive drinking or gambling.

If there are internal psychological restraints operating against the engagement with an appetitive activity, they must be more substantive than behavioural cues or reflective cognitions. One psychological restraint could be the attribute of subjective control, with the individual making a strong cognitive effort to inhibit engagement with the activity only when the individual is either in the process of developing attachment or is strongly attached. When an individual is not attached to an appetitive behaviour and engages in that behaviour at culturally acceptable levels, either some or no cognitive inhibition is needed.

4.13 A new definition of subjective control

The following is an attempt to define subjective control in addiction not in terms of what it causes but in terms of those components of the self that potentially cause addiction:

Subjective control is hypothesised to be an attribute of the mind. The elements of this attribute are ordered along a single, relevant dimension of conscious deliberation upon the engagement of the self in only those behaviours Orford (1985, 2000) terms appetitive.

The aim of the above was to propose a definition of subjective control that was not a dispositional trait (viz., did not consist of the consequences, symptoms or peculiarities pertinent to any of the appetitive behaviours). Importantly, it argues of the existence of a unidimensional attribute of conscious deliberation. As has been demonstrated throughout this chapter, subjective control, either as termed or in the guise of ‘impaired control’, has been hypothesised to be such an attribute. A possibly mistaken assumption, however, has been that unidimensionality entails quantity. This is evidenced by the use of the multivariate statistical procedure of factor analysis used in the attempts at measuring subjective/impaired control mentioned in this chapter. The above definition, with its argument that subjective control is an attribute ordered along a continuum of consciously exerted regulation enables a test of the assumption of quantity.
The adjective 'subjective' is used because the extent of the engagement in the appetitive behaviour is judged, relative to the terms defined by the individual's own experience, as requiring consciously exerted regulation. The use of this adjective is important in obtaining the most general definition of control. It is important for the reason that individuals engaging in one or more appetitive behaviours at the same level may experience different conscious capacity to regulate their engagement. This was exactly the experience of the Sobells (1973a). These researchers observed that in any sample of problem drinkers engaging in similar levels of sustained alcohol ingestion, some individuals may be able to cease their engagement at will without conscious deliberation; whereas some might feel that some conscious deliberation is required to restrict engagement whereas others, despite sustained conscious deliberation and cognitive exertion, cannot regulate their involvement at all.

Some psychological phenomena are often defined pathogenic or problematic relative to the amount of distress and disability such phenomena cause the individual. Thus it is important to understand the individual's own private experience in order to ascertain the distress and disability the individual is experiencing from the engagement in any appetitive behaviour. It is highly unlikely that for two individuals, for example, who consume alcohol at similar levels to suffer similar levels of distress and disability when one of those individuals can cease drinking at will without even thinking of consciously attempting to stop; whilst the other exerts a great deal of conscious exertion just to limit, not cease completely, the engagement. This is what Jellinek (1960) was alluding to when arguing of the psychological difference between the undisciplined versus 'lost control' drinker.

High levels of or complete subjective control is evidenced by the engagement of the self with at least one of the appetitive behaviours, where no conscious effort is made to inhibit the extent of the engagement. The engagement of the self in the appetitive behaviour does not have adverse consequences.

Moderate levels of subjective control are indicated by the engagement of the self in at least one of the appetitive behaviours where at least some conscious effort inhibits the extent of the engagement. Either the engagement causes no adverse consequences or mildly adverse consequences.

Low or non-existent levels of subjective control are indicated by the engagement of the self in at least one of the appetitive behaviours where conscious effort exerted by the
self to inhibit the engagement has not resulted in the inhibition of that engagement. The engagement causes serious adverse consequences.

If the self has protracted engagement with at least one of the appetitive behaviours and the self is experiencing harm either directly from the appetitive behaviour or from the engagement’s consequences, the self is argued to be addicted to the appetitive behaviour. As an example, this reasoning concords with an independently established definition of excessive gambling:

Problem gambling refers to the situation when a person’s gambling activity gives rise to harm to the individual player, and/or his or her family, and may extend into the community (Dickerson, et al, 1997).

The proposed definition of subjective control makes use of Orford’s (1985, 2000) seminal argument that addictions are excessive appetitive behaviours. It uses Orford’s concept to achieve Wilkinson’s (1991) aim of elucidating the aspects of the mind that the self may have to exert control over. This definition argues that it is Orford’s appetitive behaviours which are both necessary and sufficient conditions for the development of addiction. The experience of harm, however, is necessary condition of the state of addiction, but not sufficient.

As was argued in Chapters 1, 2 and 3, it is not scientifically satisfactory to simply proclaim that the proposed concept of subjective control is both unidimensional and quantitative. Within the context of the appetitive behaviour of gambling, the application to subjective control of the arguments presented in these chapters (viz., the development of a genuine interval scale measurement apparatus) is the subject of the next chapter.
Chapter 5: The construction and testing of a subjective control measurement apparatus.

It was the aim of the previous chapter to present a new definition of subjective control that might have been amenable to measurement by the theory of additive conjoint measurement (Luce & Tukey, 1964). This chapter is a report; its aim is to present this proposed empirical task and to develop suitable psychometric apparatus by applying the proposed definition of subjective control. This generated three written questionnaires referred to as the Subjective Control scales.

5.1 The twin necessities of substantive theory and stimulus control in the application of axiomatic measurement theory to psychology.

The subject matter of psychology presents great challenges to those who wish to apply the theory and methods of axiomatic measurement theory. Such applications have been rare and successful applications have been even rarer (Cliff, 1992; Narens & Luce, 1993). The reasons for this are easily identified but overcoming the problems associated with axiomatic measurement theory and psychology are genuinely very difficult and not easily solved.

Many have argued about what the problems are (Cliff, 1992; Luce, 1995; Michell, 1990, 1997b, 1999; Narens & Luce, 1986, 1993). One thing, however, that is resoundingly clear is that the theory of conjoint measurement (Luce & Tukey, 1964) in itself will not solve them. This theory, as explained in Chapter 3, is a system of axioms that pertain to natural attributes if those attributes are quantitative. In the most general way known the axioms spell out for quantities what John Stuart Mill (1845, 1925) referred to as uniformities of coexistence. When a scientist uses the theory of additive conjoint measurement, or any scientific theory of measurement, the scientist is checking to see whether or not the attribute of interest possesses the uniformities of coexistence for quantitative structure (viz., Euclid, Hölder (1901) and Luce (1987)). Hence the satisfaction of the axioms of additive conjoint measurement is no trivial matter. Given that measurement is a process of scientific observation, however, and all observation is contaminated with error to a certain extent, error invariably accompanies measurement. The uniformities of coexistence of quantitative attributes are all more or less obfuscated by error. This obfuscating effect of error has been very successfully controlled in physics, but not by the application of the classical theory of measurement per se. It has been achieved literally through centuries of persistent development of observational
technologies designed to control error; these procedures themselves based on clear, substantive physical theories.

This experience of physics has two implications for the use of determinist theories of measurement within psychology. Firstly, axiomatic conjoint measurement theory, like the classical theory of measurement in physics, is intolerant of error. The cancellation conditions of axiomatic conjoint measurement are determinist by virtue of their algebraic nature. Data contaminated by error can mislead an investigator into falsely rejecting or accepting the cancellation axioms. If the independence and Thomsen condition axioms are to be appropriately tested, an efficient method of stimulus control must be employed to mitigate the effect of error upon observations made (Michell, 1990). A great limitation in the application of axiomatic conjoint measurement is that there is no accompanying theory of error (Perline, Wright & Wainer, 1979).

Secondly, all measurement must be based within a substantive theory, regardless of the subject matter of the discipline to which measurement is applied. Any unit of measurement or scaling solution must be firmly located in a substantive theory which has empirical evidence in support of its truth. This has been entirely the experience of physics. For example, Newton’s second law of motion posits that the force of an object is the product of its mass and acceleration. The metric unit of force is the Newton, where 1 Newton equals the product of 1 kilogram of mass and 1 metre per second of acceleration (Aitchison, 1971). In Campbellian terms, force is a derived quantity, which means that the Newton is a true unit of measurement of force if and only if the multiplicative relation between mass and acceleration is true. If, hypothetically, the multiplicative relation were false and in actuality a distributive relation held such that Force = W(M + A), with W being a real-valued constant of some description, then the Newton, as a unit of measurement of force, would no longer be true. Krantz & Tversky (1971) discuss how the test of composition rules in axiomatic conjoint measurement could solve similar theoretical problems in psychology.

Fortunately, there has been developed a pertinent, substantive theory of preference behaviour within which a determinist scale of measurement can be located (viz., Coombs, 1964). There has, more recently, been a theory of stimulus control developed specifically for the construction of psychometric test statements (viz., Michell, 1998). Thus there are two empirical aims of this thesis. The first is the construction of a psychometric instrument using this theory of stimulus control for the purpose of measuring the trait of subjective control over gambling behaviour. The second is to
discover a scaling solution using the deterministic theory of preferential choice behaviour. An ancillary aim to this second aim is the testing of a recently developed probabilistic version of the determinist preferential choice theory. It too is a substantive theory from within the area of Item Response Theory (IRT). The determinist theory of preferential choice and the theory of stimulus control and construction are, respectively, discussed below. The ancillary aim to the second of the above aims will be the subject of the next chapter.

5.2 A determinist theory of preference and psychological scaling: Coombs’s (1950, 1964) theory of unidimensional unfolding.

Coombs (1950) commenced work on his determinist theory of preferential choice behaviour whilst at Harvard University and thence proceeded to publish a complete treatise on it in his 1964 monograph A Theory of Data. In it, Coombs expounded that all psychological space was Euclidean:

Data may be viewed as relations between points in a space (p.1)

Thus he made the important assumption that all psychological spaces shared the same geometrical properties of Euclidean curves and shapes. Coombs (1964) argued that the theory of unidimensional unfolding was purely a geometric algorithm by which a unidimensional psychological preference space could be discovered. That is, for preference spaces that are like points on a line. The assumptions and arguments of the unfolding theory for unidimensional preference spaces are outlined below (Michell, 1990; van der Ven, 1980).

5.2.1 Inter-observer Agreement

For any ordered finite (i.e countable) set of stimuli \( X = \langle X_i | x_1, x_2, ..., x_n \rangle \) upon which individuals exercise preferential choice, all such individuals agree about the location within the preference space of each of the elements. Many kinds of stimuli could possibly form such sets, such as political candidates, items of confectionary or statements expressing an attitude towards a particular social issue.

5.2.2 Unidimensionality

All such individuals agree that all elements within that set are ordered along one relevant dimension only. This assumption is required so that preferential choice behaviour manifested is resultant of differences between the elements of that dimension only.

5.2.3 Unidimensional Preference Space is Quantitative
This flows from Coombs’s (1964) basic arguments of the nature of psychological data. If unidimensional preference space is Euclidean like points on a line, then magnitudes within this space must obey the axioms of Hölder (1901).

**5.2.4 The theory of the Single Peaked Preference Function (Coombs & Avrunin, 1977).**

For any ordered finite set of stimuli \( X = \{X_i \mid x_1, x_2, \ldots, x_n\} \) and given unidimensionality and interobserver agreement, the theory of the single peaked preference function argues that each individual \( a \) has one and only one point of maximum preference, \( i \). For example, let the set \( X \) contains items of confectionary which are ordered according to concentration of sucrose. A group of individuals is asked to sample and appraise each of these items according to their preferred level of sweetness. Coombs & Avrunin argue that a curvilinear function \( f_{a,i} \) operates for each individual \( a \) such that a’s preference increases monotonically to a peak of maximum preference \( (i) \) and then decreases monotonically. The peak of the symmetrical preference function represents a’s *ideal point* and would represent in the above example a’s ideal level of sweetness. Importantly, this function is a property both of the individual’s proclivities and the stimuli themselves. Coombs (1964) argues the peak of the function indicates the *ideal stimulus*. For person \( a \) this can be denoted \( i_a \). The basic argument of Coombs’s (1964) theory of unidimensional unfolding is that for objects \( x_j \) and \( x_k \) (for \( j, k = 1, \ldots, n \in X \)) and for person \( a \) with a single peaked preference function \( f_{a,i} \), then:

\[
\text{a prefers } x_j \text{ to } x_k \text{ iff } |i_a - x_j| < |i_a - x_k|
\]

Equation 1 argues that person \( a \) prefers \( x_j \) to \( x_k \) if and only if the absolute magnitude of the interval between \( a \)’s ideal point and \( x_j \) is less than the absolute magnitude of the interval between the ideal point and \( x_k \). That is, \( x_j \) is the stimulus closest to \( a \)’s own preference. Hence if \( a \) was asked to make a choice from the items of confectionary, Eqn 1 predicts that item \( x_j \) would be selected. From Eqn 1 and theory of the single peaked preference function, Coombs argues the *differences* between the elements of the unidimensional preference space are quantitative. The above inequality makes clearer the above assumption of quantity. Thus it is possible, provided the theory of unidimensional unfolding is true, that the elements along this space are measurable. Such measurements, however, are unique up to positive linear transformations only (Michell, 1986; Stevens, 1946).
This limitation of measurements is by no means debilitating. It is almost always assumed that psychometric instruments of measurement are limited to providing interval scale measurements (Lord & Novick, 1968). The empirical advantage of Coombs's (1964) theory is that an interval scaling solution is not always possible to obtain. Only certain patterns of individual choice behaviour upon any set of stimuli will yield such a solution. An attractive feature of Coombs's theory is that it is possible to test empirically both the unidimensionality and quantitative aspects of the psychological preference space. This is something that cannot usually be done in psychometrics, for example, with the use of Likert's (1932) theory of summated ratings.

5.2.5 The unfolding condition

Given the single peaked preference function, inter-observer agreement and unidimensionality, Coombs (1950, 1964) argues that all stimuli in the set $X$ and all individuals' ideal stimuli are located upon the same psychological continuum. This continuum he called a joint space or J scale as both stimuli and individuals are jointly located upon it. Coombs argued that a J scale exists in the first instance as a qualitative J scale as it has yet to be determined whether individuals' preference judgements will force a simple order upon the interstimulus midpoints of the J scale. That is, the ordered metric information of a qualitative J scale is not yet known. Ordered metric information is the simple order of the magnitudes of the intervals between the stimuli. Both the interval magnitudes and their order must be uncovered empirically. Coombs argued that this empirical work is the assessment of all individual's I scales. From these I scales a simply ordered J scale is recovered which contains the pertinent ordered metric information.

An I scale is the unique rank order of the stimuli of the qualitative J scale for a particular individual $a$. How I scales are obtained is relatively straightforward. Each member of a group of individuals is asked to rank order the stimuli with respect to his or her own preference. Alternatively, all members of the group can be presented the stimuli in all possible pairs of stimuli and asked to select which stimulus in each pair is the stimulus most preferred. The latter procedure is known as the method of paired comparisons. Coombs (1950) argues that because I scales can be derived by a simple ranking task, the "... greater power of the method of paired comparisons would be unnecessary and wasted" (Coombs, 1950, p. 147). Given the possibility of intransitive rankings, however, it is entirely reasonable if respondents are requested to complete both ranking and paired comparison tasks.
Figure 1 depicts the response of person \( a \) to a hypothetical ranking task upon the set \( X \) of four confectionary items \( w, x, y \) and \( z \). The broken vertical line represents the rank order of stimuli or \( I \) scale that person \( a \) gave, which in this case is \( wxyz \). This \( I \) scale is a transitive order of the stimuli with respect to \( a \)'s preference. From this \( I \) scale it can be inferred that stimulus \( w \) is preferred to all other stimuli; and \( x \) to \( y \) and \( z \) and \( y \) to \( z \). Figure 5.1 also depicts that \( a \)'s preference function \( f_{ai} \) peaks just to the right of stimulus \( w \).

Thus \( a \)'s ideal stimulus \( i_a \) is located just to the right of \( w \). It can be imagined, as suggested by Coombs (1950) that the ideal stimulus acts like a hinge upon the \( I \) scale. This 'hinge' results in a unfolding of the \( I \) scale at \( a \)'s ideal point such that the order of stimuli along the original qualitative \( J \) scale is recovered. Thus conversely, the \( I \) scale depicted in Figure 1 can be thought of as a folding of the qualitative \( J \) scale at \( a_i \).

![Figure 5.1: The unfolding of the I scale wxyz around a's ideal point of preference, the ideal stimulus i_a. Collection of all possible I scales can enable the recovery of the original qualitative J scale.](image)

The quantitative \( J \) scale is the scale recovered through the unfolding of all \( I \) scales given by the group of individuals. The total number of stimuli permutations is \( n! \) where \( n \) is the number of stimuli. In the above example, there are four stimuli so there are \( 4! = 4 \times 3 \times 2 \times 1 = 24 \) different possible combinations. The number of \( I \) scales is significantly less than this at \( 2^{n-1} \) (Michell, 1994) given that individuals make transitive rankings of the stimuli according to their preference. In the above case of four stimuli, the number of different and transitive \( I \) scales is 8. These \( I \) scales are: a/ \( wxyz \); b/ \( xwyz \); c/ \( xywz \); d/ \( yxwz \); e/ \( xyzw \); f/ \( yxzw \); g/ \( yzw \); and h/ \( zywx \).

5.2.6 The dominant path condition
Contained in the 8 I scales mentioned above is sufficient information for the production of an ordered metric quantitative J scale. Each I scale above is a transitive folding of the qualitative J scale at a person’s ideal point and so hence can be unfolded to produce the ordered metric J scale.

Coombs (1964) argues that the I scales yield the desired ordered metric information by determining the order upon the interstimulus midpoints of the J scale. Generally, for \( n \) stimuli there exists \( \frac{1}{2} n(n-1) \) interstimulus midpoints and thus \( \frac{1}{2} n(n-1) + 1 \) interstimulus intervals. The order upon these midpoints determines both the magnitudes of the interstimulus intervals and their order. Take the above I scales \( wxyz, xwyz \) and \( xywz \). Close inspection of the first two I scales reveals that the stimuli \( w \) and \( x \) are ranked differently. Persons giving the first I scale will prefer stimulus \( w \) to all other stimuli whereas another person giving the second I scale will prefer stimulus \( x \) to all other stimuli. According to Coombs, these I scales bound the interstimulus midpoint \( wx \). The second and third I scales similarly bound the midpoint \( wy \). All three I scales tell us that the midpoint \( wx \) precedes the midpoint \( wy \), which in turn implies that for the interstimulus intervals \( \overline{wx} \) and \( \overline{wy} \) that \( |\overline{wx}| < |\overline{wy}| \). This means that the magnitude of the interval between stimuli \( w \) and \( x \) is less than the magnitude of the interval between \( w \) and \( y \). Thus some ordered metric information concerning the underlying quantitative J scale has been recovered.

The set of all eight I scales, however, does not produce a simple order upon the interstimulus midpoints. They produce instead a partial order upon them. This partial order is depicted in Figure 5.2.

![Figure 5.2: The partial order of the midpoints of the four stimuli of the qualitative J scale as given by the 8 I scales.](image)

If the midpoints are simply ordered it implies that \( \frac{1}{2} n(n-1) + 1 \) interstimulus intervals will be produced. For four stimuli this means 7 intervals. Each interval, however, has its own I scale, but for four stimuli there are eight possible I scales. In order to produce a simple order upon the interstimulus midpoints, and thus to also limit the available I scales
to $\frac{1}{2}n(n-1)+1$, Coombs (1964) argued of the *dominant path condition*. The dominant path condition is simply the path through a *proximity graph* (Michell, 1990) of all possible transitive $I$ scales that accounts for the greatest number of individuals. For example, let 25 people rank order the four items of confectionary according to their preference. Assume that all gave transitive responses. A proximity graph (Figure 5.3) for this example displays a dominant path.

```
wxzy (2)
   
wxzy (7)
   
wyxz (4)
   
wyxz (1)  xzwy (5)
   
wyxz (3)
   
wyxz (2)
   
wyxz (1)
```

Figure 5.3: A proximity graph for the eight transitive $I$ scales given by the rank orders made by 25 people. The figures in parentheses are the frequencies of each $I$ scale made by the test subjects. The dominant path is shown by the arrows with the solid heads.

The dominant path in Figure 5.3 shows that five persons gave the $I$ scale $xyzw$ as opposed to the single individual who gave the $yxzw$ $I$ scale. Only the $I$ scales in the dominant path are used to order the interstimulus midpoints, which for the above is $wx < wy < wz < xy < xz < yz$, where “<” means “precedes”. For this the order and magnitude of the interstimulus distances can be derived.

5.2.7 *Coombs’s (1964) theory and axiomatic conjoint measurement*

According to Coombs (1964), the retrieval of an ordered metric $J$ scale from a set of transitive $I$ scales supports the hypothesis that the psychological attribute of interest is unidimensional. Hence for any psychological attribute hypothesised to be unidimensional, Coombs’s theory is a tractable means of testing that hypothesis. Coombs (1964) openly suggested that his theory might find gainful employment in this way, but it has not. Psychologists and psychometricians largely have ignored the theory of unidimensional unfolding. This may be due to the theory’s incapacity to always result in a scaling solution. An unfolded ordered metric $J$ scale will not result if participants perceive that the stimuli are ordered along more than one dimension. Devising sets of
stimuli that will result in an ordered metric $J$ scale requires much hard work in the form of extensive pilot testing. Likert’s (1932) theory of summated ratings always results in a scaling solution and perhaps to the logic of the psychologists is infinitely preferable to a theory with the capacity to falsify hypotheses.

Coombs (1964) was wrong in assuming that an unfolded ordered metric $J$ scale necessarily demonstrated additive structure in the underlying attribute. Suppes & Zinnes (1963) argued that Coombs did not advance the necessary and sufficient conditions for an ordered metric scale representation. They were correct. Michell (1990, 1994a) and Doignon & Falmagne (1991, cited in Michell, 1994a) present three such conditions for unidimensional unfolding theory. Two that have already been discussed are the unfolding and dominant path conditions. But these conditions only demonstrate that the midpoints of the ordered metric $J$ scale have satisfied the single cancellation condition of additive conjoint measurement (Michell, 1990). The third necessary and sufficient condition for Coombs’ (1964) theory is the satisfaction of the hierarchy of the remaining cancellation conditions (Scott, 1964). Single cancellation, or independence, is satisfied if and only if the dominant path condition is satisfied (Michell, 1990, 1994a). These higher order conditions are to be tested if the satisfaction of the solvability, Archimedean and Thomsen condition axioms is to be achieved. This in turn requires that the qualitative $J$ scale consist of at least 6 stimuli. If these conditions can be met then Coombs’s assumption concerning the additivity of the midpoint intervals may be correct. Hence the attribute to which the $J$ scale pertains could possibly be measured on an interval scale as the automorphisms of the attribute have been found by the satisfaction of the axioms of additive conjoint measurement (Luce & Tukey, 1964) to be 2 point homogeneous and 2 point unique (Narens, 1981b; Luce et al, 1990). Coombs’s theory of single peaked preference functions and unidimensional unfolding may provide tractable theories upon which to base the scientific measurement of the psychological attributes of individuals.

Coombs’s (1964) theory is a theory of preferential choice. Unidimensional unfolding is, however, necessarily limited to a finite collection of stimuli and hence may not be able to explain all preferential choices. This makes a high demand on the highly restricted collection of stimuli presented to participants. In psychophysics and cognitive psychology, it is relatively easy to devise a class of stimuli upon which participants can perceive an unidimensional order. Hence broad participant agreement of the ordinality of the qualitative $J$ scale is very probable. This is not the case in psychometrics as the stimuli are far more complex. The stimuli are mostly written statements or test problems
designed to assess abilities. These stimuli require a greater amount of processing than psychophysical stimuli as they contain a greater amount of information. As a consequence, participants often bring to bear upon psychometric stimuli psychological factors such as attitudes, social desirability bias, personal experiences, lying and literacy skills that are not invoked in psychophysical experiments. Thus broad participant agreement of the ordinality of any qualitative J scale consisting of psychometric stimuli is difficult to achieve. Psychometric stimuli then require greater effort on the part of the researcher in their design and construction.

As mentioned previously, psychometric questionnaires pay little heed to the interrelated structure of written items and thus it is difficult to use the items contained in popular psychometric tests as stimuli in a study using Coombs’s (1964) theory. Items in a unidimensional unfolding study need an explicit structure accounting for their semantic content via their constituent predicates. This is so because on an a priori basis the purpose of items is to convey semantic information and hence participants order items on the basis of their semantic content. Michell (1994a, 1998) has devised a method by which a structure can be obtained.


To enable the unfolding condition of Coombs’s (1964) theory to apply to a unidimensional set of psychometric items, the order of the items upon the relevant, single dimension must be observable (Michell, 1994a). Michell proposed that to construct such a set of ordered items, the object and predicates of the items must be first identified. The object, subject term (Johnson, 2001) or kernel concept (Michell, 1994a) is that to which the statements will refer. In attitudinal research the object is often a social issue of a particular kind, such as homosexuality or nuclear conflict (Michell, 1994a). The predicates are the semantic components which form the written statements. It is through such predicates that the statements make their reference to the object.

Importantly, these predicates take a particular form depending upon the object. In attitudinal research, Michell (1998) argues that the predicates take an evaluative form. For example, the predicates good and bad are evaluative (Michell, 1998). Michell argues that such basic predicates are open to qualification. These predicates can be qualified by other predicates by the logical operation of conjunction. This operation is logical if and
only if the other predicates are more or less *intrinsically favourable* than the basic predicates of *good* and *bad* (Michell, 1998).

Predicate conjunction can be simply explained using symbols. Let Z represent the object or kernel concept. Let two predicates be represented by P and Q. Let the logical opposite of these predicates be represented by \( \sim P \) and \( \sim Q \), respectively. In attitudinal research, the statement *Z is P* is thus more intrinsically favourable than *Z is \( \sim P \)* (Michell, 1998). Let \( P \cdot Q \) represent the conjunction of two predicates. Then the statements

1. \( Z \) is \( P \cdot Q \),
2. \( Z \) is \( P \), \( \sim Q \), and
3. \( Z \) is \( \sim P \).

are ordered unidimensionally with respect to their intrinsic favourability towards the object Z (Michell, 1998). These conjunctions are coherent as the predicates and their logical opposites bifurcate the preceding predicate. The predicate \( P \) and its opposite \( \sim P \) bifurcate the kernel concept Z; and the predicate \( Q \) and its logical opposite \( \sim Q \) bifurcate \( P \).

An example will illustrate this further. Let \( Z \) be the representational theory of measurement. Let \( P \) be the evaluative predicate *intellectually interesting*. Let \( Q \) be the predicate *important*. Statements 1, 2 and 3 above can be written thus:

4. The representational theory of measurement is intellectually interesting and important.
5. The representational theory of measurement is intellectually interesting, but not important.
6. The representational theory of measurement is boring.

Thus the order of statements with respect to their favourability towards the kernel concept is discernible. The statements are, however, quite limited in scope as they contain only a small amount of semantic information. Further predicates can be conjoined via the process of bifurcation to make each statement more specific. This process of bifurcation results in a *binary tree* structure of all predicates and their logical opposites (Michell, 1994a, 1998). Each branch in the tree represents either a predicate or its logical opposite. Thus the node of each branch denotes a coherent bifurcation of each predicate. At the *terminus* of each branch of the binary tree is the final statement.

An example will illustrate the addition of further predicates. Take statements 4 and 5 above. Let there be another predicate \( R \) and its logical opposite \( \sim R \). Let \( R \) represent the
predicate *must be taught in a unit of psychometrics*. The predicates form the binary tree diagram of Figure 4 and symbolically the statements are as follows:

7. $Z$ is $P \cdot Q \cdot R$.
8. $Z$ is $P \cdot Q \cdot \sim R$.
9. $Z$ is $P \cdot \sim Q$.
10. $Z$ is $\sim P$.

![Binary Tree Diagram](image)

Figure 5.4. The binary tree diagram of the predicates used to construct statements 11 to 14. The symbol $t_i$ depicts the terminal node of each branch.

The new set of statements read:

11. *The representational theory of measurement is intellectually interesting, important and must be taught in a unit of psychometrics.*

12. *The representational theory of measurement is intellectually interesting and important, but does not have to be taught in a unit of psychometrics.*

13. *The representational theory of measurement is intellectually interesting, but not important.*

14. *The representational theory of measurement is boring.*

The process of bifurcation has coherently introduced additional information to a set of pre-existing predicates. The order upon the statements, however, is still discernible. Bifurcation has altered one of the final statements and has introduced another new statement (12). A Coombs (1964) scale like the one described earlier could be derived for these statements within which the unfolding condition should hold.

Michell (1998) called the set of predicates depicted in Figure 5.4 an *ordinal determinable*, as the ordinal structure of the statements relative to the kernel concept has been determined by the pattern of logically related predicates. Michell argued, however, that the predicates may actually hold more than mere ordinal information. Michell argued that all other things being equal (the *ceteris paribus* clause), the more predicates two statements share, the less attitudinal distance the two should have between them. So from the above example of four statements, statements 11 and 12 should be nearer in
attitudinal space to each other than either are to statement 14. More generally, given statements \( a, b, c \) and \( d \), the following holds, other things being equal:

\[
n(a, b) > n(c, d) \rightarrow d(a, b) < d(c, d)
\]

where \( n \) represents the number of shared nodes and the arrow represents “implies that” (Michell, 1998, Eqn 2). If this does hold over a set of statements, Michell called the structure of predicates an ordered metric determinable, as ordered metric information (Coombs, 1950) has been determined by the pattern of logically related predicates. As the order and magnitude of the interstimulus segments can infer at least a partial order upon the interstimulus midpoints, an ordered metric determinable reduces to an instance of axiomatic conjoint measurement (Michell, 1998). Six statements, however, are necessary to enable an empirical test as such. This all depends, of course, upon the ceteris paribus clause mentioned earlier. Michell stated that it is possible that other relations exist between the predicates. Such differences he suggested may result from the other (and as yet unrecognised) features of the semantic content of the predicates. Such differences could strongly influence the ordered metric information given by a set of statements structured in this way.

Michell (1998) is correct in arguing that attitude statements contain simple evaluative predicates. However, in psychometric research beyond the domain of attitudes, statements are often summaries of the individual’s own actual behaviour or personality. This is particularly the case in the development of psychometric instruments for use in clinical or psychiatric settings. Clinical or psychiatric participants are often asked to assess their agreement with statements in presented questionnaires in relation to how each statement summarises or describes their own personal behaviour. Hence predicates in these questionnaires are not evaluative, but descriptive; and thus such statements are not ordered via a transitive relation of intrinsic favourability.

Michell’s theory of the ordinal determinable can be extended to include psychometric statements that possess predicates other than evaluative ones. It is argued that statements in clinical and personality research are constructed with simple descriptive, as opposed to simple evaluative, predicates. For example, the following is an item from the Scale of Gambling Choices (SGC) (Baron, Dickerson & Blaszczynski, 1995):

\[ I \text{ have been able to stop gambling before I got into debt} \]

This statement consists of the predicate able to stop gambling before getting into debt. Note that the object of that predicate is not a social issue external to an individual. The
object is the individual's own possible behavioural experience. Hence if that is the object, a predicate must describe such a possible experience. In the case of the above item, the predicate is describing the capacity to stop gambling before getting into debt. Evaluation has a role only when an individual responds to that item. A respondent evaluates the predicate in the statement with respect to his or her own experience. After some deliberation, the individual either agrees or disagrees with the item and responds accordingly. It is possible that the individual does not understand the statement and so makes either no response or responds to a rating scale category of 'undecided', if the method of ratings is employed. To emphasise the point, often in clinical research the individual evaluates, with respect to his or her own experience, a statement describing a particular behaviour or experience. In attitudinal research, the predicates themselves evaluate a social issue of some kind; and subjects respond by examining which evaluation is closest to their own of the particular social issue.

Even though descriptive predicates are different in kind to evaluative ones, it does not mean that Michell's (1994a, 1998) theories of the ordinal determinable and ordered metric determinable cannot be used to construct statements other than those assessing attitudes. What differs is that the kernel concept \( Z \) is that of an individual's own possible, behavioural experience. If a predicate \( P \) describes at least a component of that experience, it is possible to write statements of the form \( Z \) is \( P \). If this can be done, it is also possible that other predicates can be coherently introduced to such statements using the logical operation of conjunction. These other predicates may contain information about other components of the individual's own experience that was not captured by \( P \). Thus it is possible to construct a binary tree structure of pertinent predicates which determines both an order upon the resulting statements and upon the ordered metric information (Coombs, 1950) that the set of statements possess.

5.4 The Subjective Control Scales for use in the assessment of subjective control over gambling behaviour.

It was decided that for the empirical component of this thesis that three separate binary tree structures be formed to create three separate questionnaires. These were a general scale to assess a level of general control over gambling; a time involvement scale designed to specifically address the level of control over the time spent engaging with gambling; and an impulsivity scale designed to assess subjective control over impulses to engage in gambling behaviour. This scale triumvirate was created for the following reasons. Firstly, the time involvement version was designed to accord with the theoretical
structural equation model proposed by Dickerson & Baron (2000). In that model subjective control is a latent and quantitative exogenous construct exerting influence upon the observed amount of time spent gambling. Secondly, the general and impulsivity versions were created to match the structure proposed by the items in the Scale of Gambling Choices (SGC), Baron, Dickerson & Blaszczynski, 1995), the only other psychometric test designed to assess subjective control over gambling. The items within the SGC pertain either to subjective control over gambling in general terms (eg “When I’ve wanted to I’ve been able to gamble less often”) or to subjective control over impulses to gamble (eg “I’ve been able to resist the urge to start gambling”; “When I have been near a club/hotel, TAB or casino I have found it difficult to resist gambling”).

Additionally, the questionnaires were also designed to avoid the problem mentioned in Chapter 4 of defining subjective control either operationally or as a dispositional trait. Hence no actual behaviour possibly resulting from poor subjective control over gambling (eg stealing, lying to spouses, playing until the TAB closed) was mentioned in these questionnaires. The more general and least suggestive term of ‘problems’ was used instead, proceeded always by the adverb ‘caused’.

The construction of the questionnaires is outlined below. Prior versions of these questionnaires (Appendix 1a), however, underwent extensive pilot testing. The results of these pilot studies are to be found in Appendix 1.

5.4.1. The Subjective Control scale of general control over gambling

5.4.1.1. Predicates

Let Z represent the kernel concept or object of all the statements in the general version of the Subjective Control scales. Also let Z represent the individual’s own experience of gambling behaviour. Let there be a set of predicates and their logical opposites X which logically conjoin Z and thus form a binary tree structure. The predicates of this set and the symbols that represent them are as follows:

\(~E = I never experience any need to control my gambling at all; P = I am free to gamble at my leisure; \sim P = I am not free to gamble at my leisure; Pr = My gambling causes problems; \sim Pr = My gambling does not cause problems; Ea = My gambling behaviour is relatively easy to control; \sim Tr = I do not have to make a conscious effort to control my gambling behaviour; Tr = I do have to make a conscious effort to control my gambling behaviour; \sim Th = I do not even occasionally think about reducing my gambling activity; Th = I occasionally think about reducing my gambling behaviour; Ex\)
I experience a need to control my gambling; \( \sim \text{Ea} \) = My gambling behaviour is relatively difficult to control; \( \sim \text{SPr} \) = My gambling causes few problems; \( \text{SPr} \) = My gambling causes several problems; \( \sim \text{Si} \) = My gambling causes problems of minor significance; \( \text{Si} \) = My gambling causes problems of significance; \( \sim \text{Vd} \) = My gambling behaviour is very difficult to control; \( \sim \text{Vd} \) = My gambling behaviour is not very difficult to control; \( \text{Im} \) = My gambling behaviour is impossible to control; \( \sim \text{Im} \) = My gambling behaviour is not impossible to control; \( \sim \text{Di} \) = My gambling causes significant problems that are not very distressing; \( \text{Di} \) = My gambling causes significant problems that are very distressing.

### 5.4.1.2 Terminal statements

The coherent bifurcations of the above predicates produces the following set of thirteen statements at the terminal nodes of the binary tree structure. The binary tree is depicted in Figure 5.6. The statements are represented below in symbolic form:

\[
\begin{align*}
    t_1 &= \text{Z is } \sim \text{Ex. Pl. } \sim \text{Pr} \\
    t_2 &= \text{Z is } \sim \text{Ex. Pl. Pr} \\
    t_3 &= \text{Z is } \sim \text{Ex. } \sim \text{Pl} \\
    t_4 &= \text{Z is Ex. Ea. } \sim \text{Pr. } \sim \text{Tr.} \\
    t_5 &= \text{Z is Ex. Ea. } \sim \text{Pr. Tr. Th} \\
    t_6 &= \text{Z is Ex. Ea. } \sim \text{Pr. Tr. } \sim \text{Th} \\
    t_7 &= \text{Z is Ex. Ea. Pr} \\
    t_8 &= \text{Z is Ex. } \sim \text{Ea. } \sim \text{Spr. } \sim \text{Si} \\
    t_9 &= \text{Z is Ex. } \sim \text{Ea. } \sim \text{Spr. Si} \\
    t_{10} &= \text{Z is Ex. } \sim \text{Ea. Spr. } \sim \text{Vd} \\
    t_{11} &= \text{Z is Ex. } \sim \text{Ea. Spr. Vd. } \sim \text{Im} \\
    t_{12} &= \text{Z is Ex. } \sim \text{Ea. Spr. Vd. Im. } \sim \text{Di} \\
    t_{13} &= \text{Z is Ex. } \sim \text{Ea. Spr. Vd. Im. Di}
\end{align*}
\]

### 5.4.1.3. Statements selected for use in the scale

Testing of Coombs (1964) theory of unidimensional unfolding requires a minimum of six stimuli. Hence from the above set of thirteen statements, six were selected. The theory of the ordinal determinable, however, gives rise to a set of statements that have a highly artificial and stilted form in the first instance (Michell, 1998). It is thus necessary to modify the wording of the predicates such that statements in are presented to participants in clear and less contrived forms (Michell, 1998). This is done such that each modified statement has its analogue in the set of statements produced by the ordinal
determinable. Let the modified statements be represented by the letters A, B, C, D, E & F. The following presents each selected terminal statement together with its modified analogue statement underneath it.

Statement $t_1 = Z$ is $\sim$Ex. Pl.

*I never experience any need to control my gambling at all and I am free to gamble at my leisure and My gambling does not cause problems.*

Statement A thus reads:

*I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.*

Statement $t_4 = Z$ is Ex. Ea. $\sim$Pr. $\sim$Tr.

*I experience a need to control my gambling and My gambling behaviour is relatively easy to control and My gambling does not cause problems and I do not have to make a conscious effort to control my gambling behaviour.*

Statement B thus reads:

*Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.*

Statement $t_5 = Z$ is Ex. Ea. $\sim$Pr. Tr. Th.

*I experience a need to control my gambling and My gambling behaviour is relatively easy to control and My gambling does not cause problems and I do have to make a conscious effort to control my gambling behaviour and I occasionally think about reducing my gambling behaviour.*

Statement C thus reads:

*I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems although I do think about cutting back from time to time.*

Statement $t_8 = Z$ is Ex. $\sim$Ea. $\sim$Spr. $\sim$Si.

*I experience a need to control my gambling and My gambling behaviour is relatively difficult to control and My gambling causes few problems and My gambling causes few problems of minor significance.*

Statement D thus reads:
Although my gambling is relatively difficult to control, it causes few but only minor problems.

Statement $t_{11} = \text{Ex. } \sim\text{Ea. } \text{Spr. Vd. } \sim\text{Im}$

*I experience a need to control my gambling and My gambling behaviour is relatively difficult to control and My gambling causes several problems and My gambling is very difficult to control and My gambling is not impossible to control.*

Statement E thus reads:

*My gambling is very difficult but not impossible to control, even though it causes several problems.*

Statement $t_{13} = \text{Ex. } \sim\text{Ea. } \text{Spr. Vd. } \text{Im. } \text{Di.}$

*I experience a need to control my gambling and My gambling behaviour is relatively difficult to control and My gambling causes several problems and My gambling is very difficult to control and My gambling is impossible to control and My gambling causes significant problems that are very distressing.*

Statement F thus reads:

*My gambling is impossible to control and it causes several, significant problems that are very distressing.  

5.4.2. The Subjective Control scale of control over time spent gambling

5.4.2.1. Predicates

Let $Z$ represent the kernel concept or object of all the statements in the time involvement version of the Subjective Control scales. Also let $Z$ represent the individual's own experience of gambling behaviour. Let there be a set of predicates and their logical opposites $W$ which logically conjoin $Z$ and thus form a binary tree structure. The predicates of this set and the symbols that represent them are as follows:

$\sim\text{Ex} = \text{I do not experience any need to limit the time I spend gambling; Ex = I experience the need to limit the time I spend gambling; Pl = I am free to gamble at my leisure; } \sim\text{Pl} = \text{I am not free to gamble at my leisure; Ea = It is relatively easy for me to limit the time I spend gambling; } \sim\text{Ea} = \text{It is relatively difficult for me to limit the time I spend gambling; } \sim\text{Tr} = \text{I do not have to make a conscious effort to limit the time I spend gambling; Tr = I have to make a conscious effort to limit the time I spend gambling; } \sim\text{Th}$
I do not even have to think about limiting the amount of time I spend gambling; \( Th = \) I occasionally think about limiting the amount of time I spend gambling.

\( \sim \text{In} = \) My gambling sometimes interferes with other activities; \( \text{In} = \) My gambling often interferes with other activities; \( \text{Spr} = \) My gambling causes several problems; \( \sim \text{Spr} = \) My gambling causes few problems; \( \text{Si} = \) My gambling causes problems of significance; \( \sim \text{Si} = \) My gambling causes problems of minor significance; \( \text{Vd} = \) It is very difficult for me to limit the time I spend gambling; \( \sim \text{Vd} = \) It is not very difficult for me to limit the time I spend gambling; \( \sim \text{Im} = \) It is not impossible for me to limit the time I spend gambling; \( \text{Di} = \) My gambling causes significant problems that are very distressing; \( \sim \text{Di} = \) My gambling does not cause significant problems that are very distressing.

### 5.4.2.2. Terminal statements

The coherent bifurcations of the above predicates produces the following set of fifteen statements at the terminal nodes of the binary tree structure. The binary tree is depicted in Figure 5.5. The statements are represented below in symbolic form:

\[
\begin{align*}
    t_1 &= Z \text{ is } \sim \text{Ex. Pl. } \sim \text{Pr.} \\
    t_2 &= Z \text{ is } \sim \text{Ex. } \sim \text{Pl. Pr.} \\
    t_3 &= Z \text{ is } \sim \text{Ex. } \sim \text{Pl.} \\
    t_4 &= Z \text{ is } \text{Ex. Ea. } \sim \text{Pr. } \sim \text{Tr.} \\
    t_5 &= Z \text{ is } \text{Ex. Ea. } \sim \text{Pr. Tr. Th.} \\
    t_6 &= Z \text{ is } \text{Ex. Ea. } \sim \text{Pr. Tr. } \sim \text{Th.} \\
    t_7 &= Z \text{ is } \text{Ex. Ea. Pr.} \\
    t_8 &= Z \text{ is } \text{Ex. } \sim \text{Ea. } \sim \text{In. } \sim \text{Spr. } \sim \text{Si.} \\
    t_9 &= Z \text{ is } \text{Ex. } \sim \text{Ea. } \sim \text{In. } \sim \text{Spr. } \sim \text{Si.} \\
    t_{10} &= Z \text{ is } \text{Ex. } \sim \text{Ea. } \sim \text{In. Spr.} \\
    t_{11} &= Z \text{ is } \text{Ex. } \sim \text{Ea. In. } \sim \text{Vd.} \\
    t_{12} &= Z \text{ is } \text{Ex. } \sim \text{Ea. In. Vd. } \sim \text{Im. } \sim \text{Spr.} \\
    t_{13} &= Z \text{ is } \text{Ex. } \sim \text{Ea. In. Vd. } \sim \text{Im. Spr.} \\
    t_{14} &= Z \text{ is } \text{Ex. } \sim \text{Ea. In. Vd. Im. } \sim \text{Di.} \\
    t_{15} &= Z \text{ is } \text{Ex. } \sim \text{Ea. In. Vd. Im. Di.}
\end{align*}
\]

### 5.4.2.3. Statements selected for use in the scale

Six statements were selected from the possible set of 15 statements. The wording of these statements was modified to achieve a clear and less contrived expression. These modified statements are analogues of the pertinent statements produced by the ordinal
determinable (Michell, 1998). They are represented by the letters A, B, C, D, E & F. The following presents each selected terminal statement together with its modified analogue statement underneath it.

Statement $t_1 = Z$ is $\neg EX \cdot PL \cdot \neg PR$.

I do not experience any need to limit the time I spend gambling and I am free to gamble at my leisure and My gambling does not cause any problems.

Statement A thus reads:

I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

Statement $t_4 = Z$ is $EX \cdot EA \cdot \neg PR \cdot \neg TR$.

I experience the need to limit the time I spend gambling and It is relatively easy for me to limit the time I spend gambling and I do not have to make a conscious effort to limit the time I spend gambling and My gambling does not cause problems.

Statement B thus reads:

Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

Statement $t_5 = Z$ is $EX \cdot EA \cdot \neg PR \cdot TR \cdot TH$.

I experience the need to limit the time I spend gambling and It is relatively easy for me to limit the time I spend gambling and My gambling does not cause problems and I have to make a conscious effort to limit the time I spend gambling and I occasionally think about limiting the amount of time I spend gambling.

Statement C thus reads:

I feel a need to limit the time I spend gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

Statement $t_8 = EX \cdot \neg EA \cdot \neg IN \cdot \neg SPR \cdot \neg SI$.

I experience the need to limit the time I spend gambling and It is relatively difficult for me to limit the time I spend gambling and My gambling sometimes interferes with other activities and My gambling causes few problems and My gambling causes problems of minor significance.

Statement D thus reads:
It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

Statement \( t_{13} = Z \) is Ex. ~Ea. In. Vd. ~Im. Spr.

I experience the need to limit the time I spend gambling and It is relatively difficult for me to limit the time I spend gambling and My gambling often interferes with other activities and It is very difficult for me to limit the time I spend gambling and It is not impossible for me to limit the time I spend gambling and My gambling causes several problems.

Statement E thus reads:

It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

Statement \( t_{15} = Z \) is Ex. ~Ea. In. Vd. Im. Di.

I experience the need to limit the time I spend gambling and It is relatively difficult for me to limit the time I spend gambling and My gambling often interferes with other activities and It is very difficult for me to limit the time I spend gambling and It is not impossible for me to limit the time I spend gambling and My gambling causes significant problems that are very distressing.

Statement F thus reads:

It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

5.4.3. The Subjective Control scale of control over urges to gamble

5.4.3.1. Predicates

Let \( Z \) represent the kernel concept or object of all the statements in the impulses to gamble version of the Subjective Control scales. Also let \( Z \) represent the individual’s own experience of gambling behaviour. Let there be a set of predicates and their logical opposites \( U \) which logically conjoin \( Z \) and thus form a binary tree structure. The predicates of this set and the symbols that represent them are as follows:

\[ \neg \text{Ex} = \text{I never experience strong impulses to gamble}; \text{Ex} = \text{I experience strong impulses to gamble}; \text{Pl} = \text{I am free to gamble at my leisure}; \neg \text{Pl} = \text{I am not free to gamble at my leisure}; \neg \text{Of} = \text{I sometimes experience strong impulses to gamble}; \text{Of} = \text{I often experience strong impulses to gamble}; \text{Re} = \text{The strong impulses to gamble I experience} \]
are easy to resist; \(-\text{Re}\) = The strong impulses to gamble that I experience are hard to resist; \(-\text{Tr}\) = I do not have to make a conscious effort to resist the strong impulses to gamble that I experience; \(\text{Tr}\) = I have to make a conscious effort to resist the strong impulses to gamble that I experience; \(-\text{Vd}\) = The strong impulses to gamble that I experience are not very difficult to resist; \(\text{Vd}\) = The strong impulses to gamble that I experience are very difficult to resist; \(-\text{Im}\) = The strong impulses to gamble that I experience are almost impossible to resist; \(\text{Im}\) = The strong impulses to gamble that I experience are almost impossible to resist; \(\text{Pr}\) = My gambling causes problems; \(-\text{Pr}\) = My gambling does not cause problems; \(-\text{Di}\) = My gambling does not cause significant problems that are very distressing; \(\text{Di}\) = My gambling causes significant problems that are very distressing; \(-\text{Spr}\) = My gambling causes several problems; \(-\text{Spr}\) = My gambling causes few problems; \(\text{Si}\) = My gambling causes significant problems; \(-\text{Si}\) = My gambling causes problems of minor significance.

5.4.3.2. Terminal statements

The coherent bifurcations of the above predicates produces the following set of fifteen statements at the terminal nodes of the binary tree structure. The binary tree is depicted in Figure 5.7. The statements are represented below in symbolic form:

\[
\begin{align*}
& t_1 = Z \text{ is } \sim\text{Ex. Pl. } \sim\text{Pr.} \\
& t_2 = Z \text{ is } \sim\text{Ex. Pl. } \text{Pr.} \\
& t_3 = Z \text{ is } \sim\text{Ex. } \sim\text{Pl.} \\
& t_4 = Z \text{ is } \text{Ex. Re. } \sim\text{Of. } \sim\text{Tr. } \sim\text{Pr.} \\
& t_5 = Z \text{ is } \text{Ex. Re. } \sim\text{Of. } \sim\text{Tr. } \text{Pr.} \\
& t_6 = Z \text{ is } \text{Ex. Re. } \sim\text{Of. } \text{Tr. } \sim\text{Pr.} \\
& t_7 = Z \text{ is } \text{Ex. Re. } \sim\text{Of. } \text{Tr. } \text{Pr.} \\
& t_8 = Z \text{ is } \text{Ex. Re. Of.} \\
& t_9 = Z \text{ is } \text{Ex. } \sim\text{Re. } \sim\text{Vd. Of. } \sim\text{Spr. } \sim\text{Si.} \\
& t_{10} = Z \text{ is } \text{Ex. } \sim\text{Re. } \sim\text{Vd. Of. } \sim\text{Spr. } \text{Si.} \\
& t_{11} = Z \text{ is } \text{Ex. } \sim\text{Re. } \sim\text{Vd. Of. Spr.} \\
& t_{12} = Z \text{ is } \text{Ex. } \sim\text{Re. } \sim\text{Vd. } \sim\text{Of.} \\
& t_{13} = Z \text{ is } \text{Ex. } \sim\text{Re. Vd. } \sim\text{Of.} \\
& t_{14} = Z \text{ is } \text{Ex. } \sim\text{Re. Vd. Of. } \sim\text{Im. } \sim\text{Spr.} \\
& t_{15} = Z \text{ is } \text{Ex. } \sim\text{Re. Vd. Of. } \sim\text{Im. Spr.} \\
& t_{16} = Z \text{ is } \text{Ex. } \sim\text{Re. Vd. Of. Im. } \sim\text{Di.} \\
& t_{17} = Z \text{ is } \text{Ex. } \sim\text{Re. Vd. Of. Im. Di.}
\end{align*}
\]
5.4.2.3. Statements selected for use in the scale

Six statements were selected from the possible set of 17 statements. The wording of these statements was modified to achieve a clear and less contrived expression. These modified statements are analogues of the pertinent statements produced by the ordinal determinable (Michell, 1998). They are represented by the letters A, B, C, D, E & F. The following presents each selected terminal statement together with its modified analogue statement underneath it.

Statement $t_1 = Z$ is $\sim$Ex. Pl. Pr

\begin{align*}
&I \text{ never experience strong impulses to gamble} \ \text{and} \ I \text{ am free to gamble at my leisure} \\
&\text{and} \ My \text{ gambling does not cause any problems.}
\end{align*}

Statement A thus reads:

\begin{align*}
&I \text{ am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.}
\end{align*}

Statement $t_4 = Z$ is Ex. Re. $\sim$Of. $\sim$Tr. $\sim$Pr.

\begin{align*}
&I \text{ experience strong impulses to gamble} \ \text{and} \ The \text{ strong impulses to gamble} I \\
&\text{experience are easy to resist} \ \text{and} \ I \text{ sometimes experience strong impulses to gamble} \ \text{and} \\
&\text{I do not have to make a conscious effort to resist the strong impulses to gamble that I experience} \ \text{and} \ My \text{ gambling does not cause any problems.}
\end{align*}

Statement B thus reads:

\begin{align*}
&I \text{ sometimes experience strong impulses to gamble, but I can easily resist them without any conscious effort and my gambling does not cause any problems.}
\end{align*}

Statement $t_9 = Z$ is Ex. $\sim$Re. $\sim$Of. $\sim$Tr. $\sim$Pr.

\begin{align*}
&I \text{ experience strong impulses to gamble} \ \text{and} \ The \text{ strong impulses to gamble} I \\
&\text{experience are easy to resist} \ \text{and} \ I \text{ sometimes experience strong impulses to gamble} \ \text{and} \\
&I \text{ have to make a conscious effort to resist the strong impulses to gamble that I experience} \\
&\text{and} \ My \text{ gambling does not cause any problems.}
\end{align*}

Statement C thus reads:

\begin{align*}
&I \text{ sometimes feel strong impulses to gamble and while easily resisted, it does take some} \\
&\text{conscious effort; but my gambling does not cause any problems.}
\end{align*}

Statement $t_9 = Z$ is Ex. $\sim$Re. $\sim$Vd. Of. $\sim$Spr. $\sim$Si.
I experience strong impulses to gamble and The strong impulses to gamble I experience are difficult to resist and The strong impulses to gamble that I experience are not very difficult to resist and I often experience strong impulses to gamble and My gambling causes few problems and My gambling causes problems of minor significance.

Statement D thus reads:
I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

Statement $t_{15} = Z$ is Ex. ~Re. Vd. Of. ~Im. Spr.

I experience strong impulses to gamble and The strong impulses to gamble I experience are difficult to resist and The strong impulses to gamble that I experience are very difficult to resist and I often experience strong impulses to gamble and The strong impulses to gamble that I experience are not impossible to resist and My gambling does cause several problems.

Statement E thus reads:

The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

Statement $t_{17} = Z$ is Ex. ~Re. Vd. Of. Im. Di.

I experience strong impulses to gamble and The strong impulses to gamble I experience are difficult to resist and The strong impulses to gamble I experience are very difficult to resist and I often experience strong impulses to gamble and The strong impulses to gamble that I experience are impossible to resist and My gambling causes significant problems that are very distressing.

Statement F thus reads:

My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.
Figure 5.5: Diagram of the binary tree structure of the predicates of the Subjective Control scale of control over time spent gambling. The letters represent the reworded statements analogous to those generated by the binary tree.
Figure 5.6: Diagram of the binary tree structure of the predicates of the Subjective Control scale of general control over gambling behaviour. The letters represent the reworded statements analogous to those generated by the binary tree.
Figure 5.7: Diagram of the binary tree structure of the predicates of the Subjective Control scale of control over urges to gamble. The letters represent the reworded statements analogous to those generated by the binary tree.
Figure 5.8: The dominant l scale path (open – headed arrows) as predicted by the ordinal determinables used in this thesis.

Figure 5.9: The scaling solution of statements predicted by the ordinal determinable binary tree structures used in this thesis. The solution was derived using Goode’s (1964, cited in Coombs, 1964) minimum integer algorithm of statement midpoints.
5.5 The empirical test of the Subjective Control Scales.

5.5.1 Aims
The aims of the study were fourfold. The first was to determine whether the attribute of subjective control was unidimensional. The second was to test the attribute for additivity with the theory of axiomatic conjoint measurement (Luce & Tukey, 1964). The third was to derive, depending on the success of the second aim, a scaling solution for each of the three questionnaires. The fourth was the validation of the questionnaires as psychometric instruments that can be used to assess individual levels of subjective control over gambling; particularly for use in clinical and research settings.

5.5.2 Design
The study used an anonymous, pencil and paper test-retest questionnaire design. Three criterion groups of participants received the same questionnaire. A copy of the questionnaire appears in Appendix 15. Each of the three questionnaires consisted of three sections. These parts were as follows:

5.5.2.1 Section one
This section of the questionnaires utilised an 11 – point Likert (1932) scale with the semantic categories: 0 – 2 “strongly disagree”; 2 – 4 “disagree to some extent”; 4 – 6 “fairly neutral”; 6 – 8 “agree to some extent” and 8 – 10 “strongly agree”. Each Likert scale was located underneath each statement in each of the three questionnaires. Participants were instructed that ‘0’ meant that they totally disagreed with the statement and ‘10’ meant that they totally agreed with the statement.

5.5.2.2 Section two
This section of the questionnaires consisted of bilateral paired comparison tasks. Bilateral comparisons differ to unilateral comparisons in the following manner. With the latter, participants are asked to respond to each pair of a total number of $\frac{1}{2}n(n-1)$ pairs for $n$ stimuli. For example, six statements would create a total of 15 unilateral pair comparisons. Each participant was asked to respond to all pairs by indicating the preferred statement in each pair of statements.

With bilateral comparisons, participants are first instructed to select their preferred stimulus from a set of presented stimuli. For example, a participant is instructed to select the most preferred statement from the six statements of the general version of the Subjective Control scales. Say the participant selects Statement B as the most preferred statement. The participant then completes the paired comparison task by responding to
one pertinent set of paired statements. Contained exclusively in this set are pairs of statements that are *bilateral* to the selected preferred statement. Bilateral pairs of statements contain those statements of which both are on either side of the most preferred statement. For example, for Statement B in the general version of the Subjective Control scales, Statements A & F are on either side of it. Thus the statements A & F paired together would constitute a bilateral pair comparison for Statement B, as would the pairs A & D. Each single statement has its own unique set of bilateral paired statements.

Compared to the unilateral paired comparison procedure, bilateral comparisons reduce the total number of paired comparison tasks presented to participants. A limitation of bilateral paired comparison tasks is that only enough information is obtained to ascertain each individual's folding or *I* scale (Coombs, 1964). The participants of the present study were asked in section two first to select their preferred statement and then to complete the set of bilateral paired comparisons unique to the preferred statement.

5.5.2.3 Section three

The third section of the questionnaires consisted of a preference rank ordering task. Each participant was asked simply to rank the statements within each set from the most preferred to the least preferred using the whole numbers 1 to 6. The ranking task was given to participants so that additional information concerning preference orders was available in case of intransitive or otherwise erroneous responses made in the pair comparison task.

5.5.3 Participants

It was a sampling aim of the present study to draw participants from three criterion groups. These groups were:

a/ university students who gambled occasionally;

b/ regular Electronic Gaming Machine (EGM) gamblers recruited *in situ* as they gambled;

c/ gamblers who had voluntarily referred themselves to specialist treatment clinics.

Participants successfully recruited belonged to one of the following groups:

i. Fifty seven psychology students at the University of Western Sydney who were in their first year during 2000. Seventeen identified as male and 39 as female. One participant neglected to make that record. The mean age of these participants was 21.91 years (SD = 5.73; range 18 - 53). All participants received course credit for their participation in the study.
ii. One hundred and four in situ regular EGM players. These participants were recruited from within a major gaming and sports club located in Western Sydney during November 2000. Sixty four were male and forty were female. The mean age was 25.26 years (SD = 7.88; range 18 - 55). Each participant received a gift voucher to the value of AUD$20 which could be used only within the club to purchase food and beverages only.

iii. Forty six individuals who had voluntarily referred themselves to specialist treatment clinics for treatment of their gambling behaviour. These clinics were situated within the greater Sydney metropolitan area. Thirty one were male and 15 were female. The mean age of this group was 43.67 years (SD = 13.17; range 20 - 75). Subjects were recruited during a period spanning November 2000 to October 2001. All participants received a gift voucher to the value of AUD$20 that could used at a major supermarket chain.

5.5.4 Materials

Materials employed were the Subjective Control Scales, the South Oaks Gambling Screen (SOGS) (Lesieur & Blume, 1987) and two versions of the Scale of Gambling Choices (SGC) (Baron, Dickerson & Blaszczynski, 1995; O’Connor, 2000).

5.5.5 Procedure

The administration of the questionnaires differed between the participant groups.

Student participants

Student participants were recruited using a notice posted on the Department of Psychology’s Notice Board at the Bankstown campus during July/August 2000. Participants were asked to write their names on the notice sheet at times displayed on the sheet and to turn up at those times to the location of the study.

Upon arrival, participants were seated at desks upon which were three booklets. The first booklet consisted of the three Subjective Control questionnaires. Participants were asked to complete the page requesting demographic details whilst waiting for other participants to arrive.

When all participants had arrived and had completed the demographic section, participants were read the instructions for the ratings task. This they then completed. Then the instructions for the paired comparison procedures and ranking tasks were read out to them. No more instruction was given. In the first booklet, the order of presentation of the questionnaires was the general version first, the time limit version second and the impulsivity version third. The ranking task for each questionnaire appeared at the end of the paired comparison task for each questionnaire.
Upon completion of the first booklet, participants commenced the second. This contained the two versions of the SGC (Baron, et al, 1995). The instructions for these questionnaires were not read out loud but were written in detail on the booklet. The order of the presentation of these two questionnaires alternated 50/50 between participants. This was done to control for response order bias. This booklet was essentially a filler task for participants to complete before they commenced the third booklet.

The third booklet contained the Subjective Control scales. This was the retest task designed to help establish the reliability of the Subjective Control scales. The order of presentation was reversed relative to the first booklet, however. The impulsivity questionnaire appeared first, then the time limit version, then the general version. This was also done to control for response order bias. Instructions for this booklet were not read out loud to participants, however, instructions appeared on the booklet.

Upon completion, each participant returned the questionnaire to the researcher and the researcher then completed the details necessary for the participant to obtain course credit for participation.

**In situ EGM gambler participants**

The in situ EGM gamblers were recruited somewhat differently. The location of the study was in the meal room of the sports club itself. An employed female assistant carrying a copy of the information sheet and a gift voucher recruited potential participants from the gaming area of the sports club. Interested club patrons were escorted by the assistant to the meal room and introduced to the researcher. The researcher then seated the participants at tables and placed the booklets and pens in front of them. These participants completed the questionnaires as per the student participants except that no instructions at all were read out. All instructions appeared in written form on the booklets, yet the researcher was on hand to answer any questions. Upon completion of the questionnaires, the researcher checked each questionnaire and then gave a gift voucher to each participant. The participant was then thanked.

**Self – referred problem gambler participants**

The group of self-referred problem gamblers was administered the questionnaires by their therapists / counsellors in private without the researcher being present. Potential participants were informed about the study by their therapists. It was at the therapists’ discretion as to whether they were informed of the study. The researcher requested of the therapists that potential participants be literate in English. The booklets were exactly the same as those presented to the club gamblers. When each participant completed the
questionnaires, the participant was thanked by the therapist for participating in the study and was given the gift voucher.

5.5.6 Results

5.5.6.1 Demographics

Gambling upon EGMs was by far the most popular form of gambling in all three participant groups. Thirty point nine percent of the student group nominated EGMs as the favourite form, with the next most popular forms being cards (18.2%), lotteries (14.5%) and on course betting on greyhounds or horses (10.9%). The least favourite forms were the casino and card machines (1.8% each). Fifty – five percent of in situ club gamblers nominated EGMs as the favourite form, with next most popular forms being on course betting (20%) and the casino (7%). The least favourite for the club gamblers was lotteries (1%). Sixty four point four percent of the self-referred problem gamblers nominated EGMs as their most favourite form of gambling, with the next most popular being on course betting (17.8%) and off course betting (Totaliser Agency Betting, TAB) and the casino (6.7% and 8.9%, respectively). The least favourite form was cards (2.2%). Ten participants in total did not nominate a favourite form of gambling. These results strongly indicate a preference for the continuous forms of gambling (viz., EGMs and on/off course betting) amongst all participants.

Unfortunately, graphical analysis suggested the other demographic data were highly positively skewed, thus negating the use of parametric statistical analysis. In most instances, the standard deviation was larger than the mean. Nevertheless, the student and in situ club gamblers spent numerically similar amounts per session of gaming (mean = AUD$66.74, SD = 280.00, median = 10; and mean = AUD$67.63, SD = 101.17, median = 30, respectively). Self – referred problem gamblers (two such participants did not indicate their expenditure) spent considerably more (mean = AUD$259.46, SD = 290.10, median = 180) than either the student or club gamblers.

As expected, the self-referred problem gamblers were very frequent gamblers. The mean frequency of gaming sessions per year for this group was 365.15 (SD = 685.45; median = 208). The yearly frequency of gaming sessions was smaller for the student group (mean = 44.18, SD = 59.57, median = 24) than for the club gamblers (mean = 92.29, SD = 195.48, median = 52). If the medians are interpreted as more accurate indicators of central tendency than the arithmetic mean, self – referred problem gamblers gambled on average four times per week, the in situ club gamblers once per week and the
student gamblers slightly less than once per fortnight. Fourteen participants in total did not indicate their frequencies of gambling.

5.5.6.2 Unfolding data, error rates, axiom testing and scaling solutions

Six participants did not complete the retest booklet. One participant (a self referred problem gambler) completed neither the test nor retest booklets. All other participants' responses to the bilateral paired comparison tasks in each of the three questionnaires were assessed to obtain the data necessary for the test of unidimensionality (viz., an unfolded $J$ scale).

The error rates of the paired comparison data are in Tables 1 to 4. Overall error rates (Table 1) were calculated by counting the number of absent or intransitive pair comparisons made by each participant, then summing across all participants. This was done for each version of the Subjective Control scales under both test and retest conditions. The error rates for each group of participants (Tables 2 to 4) were calculated in the same way, except errors were summed over all participants in each particular group rather than overall. This was again done for each version of the Subjective Control scales under both test and retest conditions.

Where errors such as intransitive or absent pair comparison tasks were present, data concerning participants' preference orders in the ranking task were used to retrieve transitive $I$ scales. In the cases where participants either neglected to respond to all required pair comparison tasks or gave entirely incorrect responses, those participants' ranking data were used to retrieve their $I$ scales, providing of course that such ranks were transitive (see Table 5). Ranking and rating task data were recorded as they were observed. Test and retest data were analysed separately.

It was found that all three questionnaires yielded a unidimensional, unfolded $J$ scale (Coombs, 1964) for each of the three questionnaires. The dominant paths discovered in the test data were replicated in the retest data. Thus the hypothesis of unidimensionality of subjective control was supported by these findings. Moreover, the axioms of conjoint measurement were also satisfied for all three questionnaires, suggesting also that that attribute may be quantitative. Importantly, however, the dominant paths through the $I$ scales obtained were not those predicted by the theory of the ordinal determinable in Figure 5.8.
Table 5.1: Overall pair comparison error rates of the three versions of the Subjective Control scales.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Errors</td>
<td>173</td>
<td>152</td>
<td>173</td>
<td>172</td>
<td>186</td>
<td>190</td>
</tr>
<tr>
<td>Pairs</td>
<td>1070</td>
<td>1031</td>
<td>1072</td>
<td>1020</td>
<td>1078</td>
<td>1030</td>
</tr>
<tr>
<td>Ratio</td>
<td>.162</td>
<td>.147</td>
<td>.161</td>
<td>.169</td>
<td>.173</td>
<td>.184</td>
</tr>
</tbody>
</table>

(Gen = general; T.L = Time Limit; Imp. = Impulsivity)

Table 5.2: Student – group pair comparison error rates of the three scale versions.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Errors</td>
<td>28</td>
<td>24</td>
<td>21</td>
<td>34</td>
<td>27</td>
<td>28</td>
</tr>
<tr>
<td>Pairs</td>
<td>291</td>
<td>292</td>
<td>291</td>
<td>291</td>
<td>293</td>
<td>292</td>
</tr>
<tr>
<td>Ratio</td>
<td>.096</td>
<td>.082</td>
<td>.072</td>
<td>.117</td>
<td>.092</td>
<td>.096</td>
</tr>
</tbody>
</table>

(Gen = general; T.L = Time Limit; Imp. = Impulsivity)

Table 5.3: In situ club gambler – group pair comparison error rates of the three scale versions.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Errors</td>
<td>78</td>
<td>81</td>
<td>101</td>
<td>84</td>
<td>91</td>
<td>102</td>
</tr>
<tr>
<td>Pairs</td>
<td>538</td>
<td>511</td>
<td>536</td>
<td>499</td>
<td>537</td>
<td>500</td>
</tr>
<tr>
<td>Ratio</td>
<td>.145</td>
<td>.159</td>
<td>.188</td>
<td>.168</td>
<td>.169</td>
<td>.204</td>
</tr>
</tbody>
</table>

(Gen = general; T.L = Time Limit; Imp. = Impulsivity)

Table 5.4: Self-referred problem gambler – group pair comparison error rates of the three scale versions.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Errors</td>
<td>67</td>
<td>47</td>
<td>51</td>
<td>54</td>
<td>68</td>
<td>60</td>
</tr>
<tr>
<td>Pairs</td>
<td>241</td>
<td>228</td>
<td>245</td>
<td>230</td>
<td>248</td>
<td>238</td>
</tr>
<tr>
<td>Ratio</td>
<td>.278</td>
<td>.206</td>
<td>.208</td>
<td>.235</td>
<td>.274</td>
<td>.252</td>
</tr>
</tbody>
</table>

(Gen = general; T.L = Time Limit; Imp. = Impulsivity)

Table 5.5: Number of totally erroneous pair comparisons and number of successful / scale retrievals.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td># erroneous comps.</td>
<td>19</td>
<td>8</td>
<td>9</td>
<td>11</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td># retrievals</td>
<td>13</td>
<td>6</td>
<td>9</td>
<td>6</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>

(Gen = general; T.L = Time Limit; Imp. = Impulsivity)

Tables 5.1 to 5.4 indicate that paired comparison error rates varied between the criterion groups. The student gamblers exhibited the lowest error rates with all paired comparison
tasks in both phases being less than 10%, except for the time limit questionnaire in the retest phase. The in situ club gamblers made noticeably more errors which were highly variable across the questionnaires. The error rates ranged from 15% in the general questionnaire in the test phase to 21% for the impulsivity questionnaire in the retest phase. The self-refered problem gamblers exhibited the worst and most variable error rates. Rates varied from 21% for both the general and time limit questionnaires in the retest and test phases, respectively, to 28% for the general questionnaire in the test phase.

Overall error rates, however, remained stable across phases. To test this stability statistically, paired samples $t$-tests were undertaken upon the mean error rates per participant. For the general questionnaire, there was no significant difference ($t(197) = .66, p = .51$) between the mean participant error rate in the test phase ($M = .82, SD = 1.46$) and retest phase ($M = .75, SD = 1.33$). For the time limit questionnaire, no significant difference was found ($t(196) = -.551, p = .58$) between the test ($M = .79, SD = 1.41$) and retest ($M = .85, SD = 1.5$) phases. For the impulsivity questionnaire, no significant difference was found ($t(199) = -.333, p = .74$) between the test ($M = .91, SD = 1.56$) and retest ($M = .95, SD = 1.57$) phases.

Despite this error, dominant paths were attained (please refer to Figures 5.10 to 5.15). Only between 2 – 6% of transitive $I$ scales made by participants fell outside of the dominant path in each of the three questionnaires. As can be seen, the dominant paths of the general and impulsivity versions of the Subjective Control scales were also discovered in the data of the retest condition. This finding strongly suggests two conclusions. Firstly, that the dominant paths discovered in the test data are robust phenomena. Secondly, that the deviance of the dominant paths from the one predicted (see Fig. 5.8) was not trivial.

Interestingly, there was a 'loop' discovered in the dominant path of the test condition data from the time involvement version of the Subjective Control scales (Fig.5.12). This 'loop' is actually a partial order upon the interstatement midpoints. This partial order almost manifested in the retest data (Fig.5.13). This may indicate a problem with Statements D and E in the time involvement version of the Subjective Control scales.

Figures 5.16 and 5.17 display the tests of double cancellation condition upon the midpoint orders of all dominant paths of Figs. 5.10 – 5.15. All tests displayed are acceptances of the condition. They are all acceptances as the consequent relations (depicted by the open arrows) do not in any instance contradict both antecedent relations (Michell, 1988, 1990). Hence the midpoint orders of each of the three versions of the
Subjective Control scales satisfy the axioms of additive conjoint measurement (Luce & Tukey, 1964). Thus the data are consistent with the hypothesis that the subjective attributes involved are quantitative. The scaling solutions depicted in Figs. 5.18 & 5.19 can hence be interpreted as measures of subjective control up to positive linear transformations only (Michell, 1986).
Figure 5.10: The dominant scale path found in the test data of the general version of the Subjective Control scales. Broken line arrows indicate relationships between dominant path scales and those scales falling outside of the dominant path. Numbers in parentheses indicate the number of subjects making that transitive preference order.
Figure 5.11: The dominant / scale path as discovered in the retest data for the general scale version.
Figure 5.12: The dominant I scale path discovered in the test data from the Subjective Control scale of control over time spent gambling. Note the split in the lower part of the diagram indicating a partial order upon the interstimulus midpoints.
Figure 5.13: The dominant / scale path as discovered in the retest data of the time involvement version of the Subjective Control scales.
Figure 5.14: The dominant I scale path discovered in the test data of the Subjective Control scale of control over urges to gamble.
Figure 5.15: The dominant scale path discovered in the retest data of the urges to gamble version.
Figure 5.16: Satisfactory tests of the double cancellation condition of axiomatic conjoint measurement (Luce & Tukey, 1964) upon the interstatement midpoint orders found in the unfolding data. These tables test the midpoint order displayed in Figure 5.19. Solid arrows indicate the antecedent relations. Open arrows indicate the consequent relation.
Figure 5.17: Satisfactory tests of the double cancellation condition of axiomatic conjoint measurement upon the interstatement midpoint orders found in the unfolding data. These tables test the midpoint order displayed in Figure 5.18. Solid arrows indicate the antecedent relations. Open arrows indicate the consequent relation.
Figure 5.18: A minimum integer algorithm (Goode, 1964, cited in Coombs, 1964) scaling solution for the impulsivity questionnaire. It is also a solution for the time limit questionnaire if the right-hand branch of the dominant path (Fig. 5.12) is chosen to order the midpoints.

Figure 5.19: A minimum integer algorithm (Goode, 1964, cited in Coombs, 1964) scaling solution for the general questionnaire. It is also a solution for the time limit questionnaire if the left-hand branch of the dominant path loop (Fig. 5.12) is chosen to order the midpoints.

5.5.6.3 Assessment of scale reliability

A certain difficulty is presented to the researcher who employs Coombs’ (1964) theory of unidimensional unfolding in the development of psychometric apparatus. This difficulty is the assessment of scale reliability. According to classical test theory (Lord & Novick, 1968), the reliability of a scale is ascertained by calculating the ratio of true score variance to observed score variance. It is argued that if the value of this ratio is near one then the observed score variance can be attributed to true score variance (Traub & Rowley, 1991). True scores, however, are held to be unobservable and thus the ratio of true score to observed score variances cannot be directly computed.

It is argued, however, that for any two sets of observed scores given by respondents on separate occasions, the value of the product moment correlation between these sets of scores will approximate the true to observed score variance ratio (Frisbie, 1988; Traub & Rowley, 1991). The higher the positive magnitude of the product moment correlation coefficient, the more reliable the scale is argued to be. With this coefficient calculated, the standard error of measurement (Lord & Novick, 1968) can be estimated. This is given by the formula $\delta_c = \delta_s \sqrt{1 - r_{xx}}$ (Lord & Novick, 1968, p. 59, Eqn 3.3.9), where $\delta_s$ is standard deviation of observed scores and $r_{xx}$ the test–retest product moment correlation.

Coombs’ (1964) theory, however, does not present arguments concerning observed, true or error scores. His theory argues given special conditions (viz., the unfolding and dominant path conditions) ordinal preference information can be obtained from respondents who assess a set of stimuli hypothesised to be ordered along a single,
relevant dimension. This preference information can then be used to assess the ordered metric information underlying the presented stimuli. Moreover, the theory of the response process, the single peaked preference function (Coombs & Avrunin, 1977), argues that both the locations of the stimuli and respondents’ preferences are not stochastic. Hence the calculation of a statistic such as the product moment correlation coefficient to infer the reliability of a Coombs (1964) based scale is problematic.

Nevertheless, it is highly probable that participants’ responses to paired comparison, ranking and rating scale tasks will vary between test and re-test administrations of the scale. It is also possible that such variation may be in part influenced by the properties of the scale. Hence it may not be unreasonable to calculate correlation coefficients upon each of these kinds of data between test and re-test conditions. Thus it may be possible to at least infer the reliability of a Coombs derived instrument by investigating the consistency of participants’ responses across test conditions.

Participants’ ratings of each statement in each of the Subjective Control scales were correlated with their respective retest ratings using the parametric Pearson’s $r$ product moment procedure. The pertinent co-efficient values are presented in Table 5.6. Participants’ rankings of each statement in each scale were correlated with the respective retest data using the Kendall’s tau-b procedure. The pertinent co-efficient values are presented in Table 5.7. Correlations were performed using the SPSS for Windows (Version 10) computer program.

<table>
<thead>
<tr>
<th>Version</th>
<th>Statement A</th>
<th>Statement B</th>
<th>Statement C</th>
<th>Statement D</th>
<th>Statement E</th>
<th>Statement F</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>.725***</td>
<td>.485**</td>
<td>.568**</td>
<td>.566**</td>
<td>.648**</td>
<td>.811**</td>
</tr>
<tr>
<td>Time Inv</td>
<td>.699**</td>
<td>.555**</td>
<td>.455**</td>
<td>.667**</td>
<td>.611**</td>
<td>.813**</td>
</tr>
<tr>
<td>Impulses</td>
<td>.767**</td>
<td>.505**</td>
<td>.514**</td>
<td>.569**</td>
<td>.697**</td>
<td>.780**</td>
</tr>
</tbody>
</table>

** $p < .01$ two tailed tests; † $n = 203$; ‡ $n = 200$; § $n = 202$.

<table>
<thead>
<tr>
<th>Version</th>
<th>Statement A</th>
<th>Statement B</th>
<th>Statement C</th>
<th>Statement D</th>
<th>Statement E</th>
<th>Statement F</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>.864**</td>
<td>.745**</td>
<td>.551**</td>
<td>.552**</td>
<td>.773**</td>
<td>.671**</td>
</tr>
<tr>
<td>Time Inv</td>
<td>.844**</td>
<td>.758**</td>
<td>.736**</td>
<td>.691**</td>
<td>.804**</td>
<td>.785**</td>
</tr>
<tr>
<td>Impulses</td>
<td>.888**</td>
<td>.827**</td>
<td>.726**</td>
<td>.693**</td>
<td>.827**</td>
<td>.835**</td>
</tr>
</tbody>
</table>

** $p < .01$ two tailed tests; † $n = 196$; ‡ $n = 191$; § $n = 194$.

The results in Table 5.6 are moderate to high, positive Pearson’s $r$ coefficient values. This suggests that participants’ responses to the rating scale task were consistent between test and re-test administrations of all three versions of the Subjective Control scales. The
magnitudes of the Kendall’s tau-b coefficients (Table 5.7) were slightly greater than the coefficients in Table 5.6. The tau-b coefficients for Statements B, C and E across all three scales were noticeably higher than their respective \( r \) coefficients. These results may support Michell’s (1998) suggestion that rating scale tasks may not capture all possible ordinal preference information due to the possibility of respondents making tied ratings. It is possible, however, that participants remembered well their responses made to each scale in the test condition. These memories may have influenced participants’ responses to the scales in the re-test condition. This memory effect may have exaggerated the magnitude of the coefficients displayed in Tables 5.6 & 5.7.

Kendall’s tau-b correlations between the pair comparison and ranking tasks were calculated by converting all \( I \) scales (including intransitive preference orders) obtained into ranks and then correlating them with the ranking task data. The only data excluded from the analysis were from those \( I \) scales derived entirely from the ranking task (i.e. those incidents where the pair comparison data were missing or totally erroneous). It was reasoned that such data would exaggerate the magnitude of the correlations if included.

The coefficients for the data obtained in the test phase are presented in Table 5.8 and those for the data obtained in the retest phase in Table 5.9. The coefficients display magnitudes between .57 and .95, with the majority being greater than .7. This indicates that participants’ responses to the paired comparison and ranking tasks varied, but not greatly. Such variation is in keeping with Coombs’ (1964) expectation that individuals’ ideal preferences can ‘oscillate’ temporally.

<table>
<thead>
<tr>
<th>Version</th>
<th>Statement A</th>
<th>Statement B</th>
<th>Statement C</th>
<th>Statement D</th>
<th>Statement E</th>
<th>Statement F</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>.862**</td>
<td>.754**</td>
<td>.630**</td>
<td>.572**</td>
<td>.793**</td>
<td>.801**</td>
</tr>
<tr>
<td>Time</td>
<td>.891**</td>
<td>.836**</td>
<td>.696**</td>
<td>.741**</td>
<td>.882**</td>
<td>.860**</td>
</tr>
<tr>
<td>Impulses</td>
<td>.896**</td>
<td>.825**</td>
<td>.722**</td>
<td>.777**</td>
<td>.862**</td>
<td>.940**</td>
</tr>
</tbody>
</table>

** \( p < .01 \), two tailed tests; † \( n = 193 \); § \( n = 196 \).

<table>
<thead>
<tr>
<th>Version</th>
<th>Statement A</th>
<th>Statement B</th>
<th>Statement C</th>
<th>Statement D</th>
<th>Statement E</th>
<th>Statement F</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>.913**</td>
<td>.841**</td>
<td>.779**</td>
<td>.768**</td>
<td>.831**</td>
<td>.822**</td>
</tr>
<tr>
<td>Time</td>
<td>.899**</td>
<td>.867**</td>
<td>.797**</td>
<td>.760**</td>
<td>.867**</td>
<td>.893**</td>
</tr>
<tr>
<td>Impulses</td>
<td>.929**</td>
<td>.802**</td>
<td>.749**</td>
<td>.797**</td>
<td>.804**</td>
<td>.898**</td>
</tr>
</tbody>
</table>

** \( p < .01 \), two tailed tests; † \( n = 191 \); ‡ \( n = 182 \); § \( n = 183 \).
5.5.6.4 Assessment of criterion, concurrent and discriminative validity

Like reliability, ideas concerning the validity of psychometric instruments are associated with classical test theory (Lord & Novick, 1968). Hence the assessment of validity is rendered problematic when Coombs's (1964) theory of unidimensional unfolding has employed as the basis for scale construction. Validity is most commonly assessed by calculating product moment correlation coefficients between scale respondents' observed scores and measurements of other variables (Messick, 1989). According to classical test theory, the absolute values of such correlations are symmetric validity coefficients (Lord & Novick, 1968, p. 61). For example, a test of verbal ability is administered to a group of school children. The observed scores obtained may be correlated with the children's marks on exams and assignments to establish criterion (or predictive) validity.

Similar to the problem encountered with reliability, the theory of the single peaked preference function (Coombs & Avrunin, 1977) argues that stimuli locations and respondents' preferences are not stochastic. It is highly probable, however, that the external variables will vary stochastically. Hence it may not be unreasonable to correlate the I scale values obtained by the Goode's algorithm (Coombs, 1964) method with the values of the external scores or measurements.

Each participant except those who gave no I scale information at all (that is, they did not respond either to the ranking or paired comparison tasks) were assigned values from the scales depicted in Figs. 17 & 18. As each transitive, dominant path I scale is located in an inter-midpoint interval, such I scales were assigned the value marking equidistance from each midpoint. The I scales ABCDEF and FEDCBA were not assigned values in this manner because these particular I scales are not nested between two interstimulus midpoints. They were assigned, respectively, the values of the statements A and F. Intransitive preference orders and I scales not located on the dominant path were assigned the value belonging to the nearest dominant path I scale.

In order to ascertain the predictive (criterion) validity of the Subjective Control scales, participants' I scale values from each test - phase questionnaire and frequency of gambling and total expenditure per session were correlated using the Pearson product moment procedure. The results are presented in Tables 5.10 & 5.11.
Table 5.10. Pearson’s r correlations between the test / scale values and frequency of gambling and session expenditure.

<table>
<thead>
<tr>
<th></th>
<th>Gen test</th>
<th>TL test (l.b)</th>
<th>T.L test (r.b)</th>
<th>Imp. test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency†</td>
<td>.38**</td>
<td>.35**</td>
<td>.35**</td>
<td>.35**</td>
</tr>
<tr>
<td>Expenditure‡</td>
<td>.45**</td>
<td>.44**</td>
<td>.42**</td>
<td>.47**</td>
</tr>
</tbody>
</table>

** p < .01 one tailed tests; † n = 195; ‡ n = 205.

Table 5.11. Pearson’s r correlations between the retest / scale values and frequency of gambling and session expenditure.

<table>
<thead>
<tr>
<th></th>
<th>Gen retest</th>
<th>TL retest (l.b)</th>
<th>T.L retest (r.b)</th>
<th>Imp. retest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency†</td>
<td>.40**</td>
<td>.36**</td>
<td>.35**</td>
<td>.38**</td>
</tr>
<tr>
<td>Expenditure‡</td>
<td>.46**</td>
<td>.42**</td>
<td>.41**</td>
<td>.45**</td>
</tr>
</tbody>
</table>

** p < .01 one tailed tests; † n = 188; ‡ n = 198.

The magnitudes of these coefficients suggest that there is a moderate, positive relationship between participants’ I scale values and self-reported levels of session expenditure and frequency of play. The square values of these coefficients can be calculated to ascertain the proportion of variance predicted by the Subjective Control scales of the criterion variables. In all cases, the variance is less than 25%. This then indicates that the relationship between the Subjective Control scales and the criterion variables is small rather than moderate. Thus the criterion validity of the Subjective Control scales could be weak.

In order to ascertain the concurrent validity of the Subjective Control scales, participants’ total scores on both the 12 item (O’Connor, 2000) and 18 item (Baron, Dickerson & Blaszczynski, 1995) versions of the Scale of Gambling Choices were correlated with I scale values using the Pearson product moment procedure. The results are presented in Tables 5.12 & 5.13.

Table 5.12. Pearson’s r correlations between the test / scale values and total scores of both versions of the SGC (n = 208).

<table>
<thead>
<tr>
<th></th>
<th>Gen test</th>
<th>TL test (l.b)</th>
<th>T.L test (r.b)</th>
<th>Imp. test</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 item SGC</td>
<td>.69**</td>
<td>.68**</td>
<td>.71**</td>
<td>.71**</td>
</tr>
<tr>
<td>12 item SGC</td>
<td>.81**</td>
<td>.81**</td>
<td>.83**</td>
<td>.82**</td>
</tr>
</tbody>
</table>

** p < .01 one tailed tests

Table 5.13. Pearson’s r correlations between the retest / scale values and total scores of both versions of the SGC (n = 200).

<table>
<thead>
<tr>
<th></th>
<th>Gen test</th>
<th>TL test (l.b)</th>
<th>T.L test (r.b)</th>
<th>Imp. test</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 item SGC</td>
<td>.70**</td>
<td>.70**</td>
<td>.73**</td>
<td>.75**</td>
</tr>
<tr>
<td>12 item SGC</td>
<td>.82**</td>
<td>.81**</td>
<td>.83**</td>
<td>.83**</td>
</tr>
</tbody>
</table>

** p < .01 one tailed tests
The magnitudes of these coefficients suggest that there is a strong, positive relationship between participants’ I scale values and their total SGC scores. This suggests good concurrent validity of the Subjective Control Scales with the SGC, more so with the 12 item version.

In order to ascertain the clinical, discriminative validity of the Subjective Control Scales, the I scales given by the group of self-referred problem gamblers were assessed with their scores on the South Oaks Gambling Screen (SOGS, Lesieur & Blume, 1987). Only participants whose score either equaled or exceeded the Australian cutoff score of 10 for diagnosis of problem gambling were used for analysis.

It must be noted that the students and the in situ club EGM gamblers were not administered the SOGS. The SOGS is not a psychometric instrument purporting to measure some kind of psychological attribute. It is a diagnostic screen designed for clinical use by a trained clinician. Thus for the purposes of the present study, it was not deemed appropriate for the students and in situ club gamblers to be administered the SOGS.

One clinic from which six participants were recruited did not make SOGS data available and thus these participants’ responses were excluded from this analysis. Another six participants scored under the cut off score of 10, however, one participant did satisfy the DSM IV + (APA, 1994) criteria for ‘pathological’ gambling. These participants were also excluded except for this particular participant. This left 36 participants whose cutoff scores were greater than or equal to 10 plus the DSM diagnosed participant.

<table>
<thead>
<tr>
<th>Arith. mean</th>
<th>16.99</th>
<th>15.88</th>
<th>12.28</th>
<th>13.32</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.D</td>
<td>7.44</td>
<td>7.85</td>
<td>5.04</td>
<td>4.66</td>
</tr>
<tr>
<td>median</td>
<td>16.5</td>
<td>16.5</td>
<td>13.75</td>
<td>13.75</td>
</tr>
<tr>
<td>mode</td>
<td>24</td>
<td>24</td>
<td>17</td>
<td>17</td>
</tr>
</tbody>
</table>

As can be seen from Table 5.14, the modal value was also the scale value of Statement F which indicated the lowest level of subjective control. The number of participants recording such a value for the general, time limit (left branch), time limit (right branch) and impulsivity questionnaires were 16, 14, 14 & 18 respectively. The frequency of participants having I scale scores corresponding to the next higher preference orders EFDCBA and EDFCBA of the general, time limit (left branch), time limit (right branch) and impulsivity questionnaires were, respectively, eight, 13, 13 and 11. Thus between 66
- 80% of participants who gave a SOGS cutoff score of 10 or greater gave either Statement E or Statement F, the statements describing the least subjective control, as their preferred statement. This suggests that the Subjective Control scales possessed the capacity to identify those gamblers who may be experiencing problems with their gambling.

5.6 Factor analyses of the rating scale data and the ‘extra factor phenomenon’ (Coombs, 1975)

The most favoured analytical technique employed in the development of psychometric apparatus is factor analysis (Thurstone, 1947; Kline, 1998); a statistical technique whose inception is accredited to the early quantitative psychologist Charles Spearman (1904) and his work on intelligence assessment. Chapter Four discussed the widespread use of factor analysis in the addiction field with respect to the construction of various tests. Factor analysis is used predominantly for the purpose of assessing the construct validity of a test (Kline, 1998). Hence as an additional test of the validity of the Subjective Control scales, it was thought that the rating scale data should be subjected to factor analysis.

The basic orthogonal (additive, non-correlated) factor analysis model can be expressed as:

\[ z_{ij} = F_{k1}Z_{i1} + F_{k2}Z_{i2} + \ldots + F_{kn}Z_{in} + \varepsilon_{ij} \quad 3. \]

where \( z_{ij} \) is \( i \)'s total score on test \( j \) in standardised form, \( \{Z_{i1}, Z_{i2}, \ldots, Z_{in}\} \) is a vector of the unobserved, standardised 'amounts' that \( i \) possess' of \( n \) unobserved, latent factors, \( \{F_{k1}, F_{k2}, \ldots, F_{kn}\} \) is a vector of observed weights or 'loadings' derived from the data upon the \( n \) and \( \varepsilon_{ij} \) is the total error term (Harris, 2001; Johnson & Wichern, 1998). The vector of Z scores can be interpreted as \( i \)'s location upon the relevant dimensions and the \( F \) loadings indicate the degree to which the test assesses the unobserved factors. These loadings range between 0 and 1 and ideally should approach or be close to 1 if the test is a good measure of the unobserved factors. If the factor analysis results in the above orthogonal model, then each of the \( F \)'s can be squared and then summed to give the communality of an item within the test, which indicates how much of the observed score variance for each item the factor analysis model accounts for (Kline, 1998).

Within psychology, the factors comprising the factorial solution of a relevant empirical study are interpreted almost unanimously to each represent a single, unidimensional attribute. Consistent with such interpretation, it would be expected that a factor analysis
performed upon the rating scale data derived from statements used in a study of unidimensional unfolding would result in a single factor factorial solution; given the precondition that the assumptions of Coombs's theory (1964) had been met. Thus it could be hypothesised that the ratings data obtained in the present study would yield a single factor solution for each version of the Subjective Control scales, given that the conditions of both Coombs's (1964) theory and the theory of axiomatic conjoint measurement (Luce & Tukey, 1964) were satisfied. It turns out that such an hypothesis, however, is untenable.

Empirical research has found that principal component analyses conducted upon the correlation matrices of items used in unfolding studies yield two factors as opposed to the expected single factor (Coombs, 1964; Davison, 1977; Green, 1988; Ross & Cliff, 1964; Russell, 1980). The occurrence of a two factorial solution in the decomposition of the correlation matrix generated by unfolding stimuli was first noted by Coombs & Kao (1960) and was thence termed by Coombs (1964, 1975) as the extra factor phenomenon.

In attempt to explain the occurrence of this phenomenon, Coombs (1964, 1975) suggested that an individual's preference space may consist of a 'semihypersphere' consisting of \( r \) unfolded dimensions (or genotypic spaces) and \( r + 1 \) factors which he termed the factor space. The existence of a single genotypic space thus results in a factor space comprising two orthogonal factors. The second factor Coombs (1964) argued was a utility factor. The higher the projection of an individual's location upon this factor is, the more to the centre of the 'distribution' of persons that individual is; and so ‘...hence the nearer he is to the others on the average and the better he represents them’ (p.182).

This is a rather unwieldy theoretical explanation for the two-factor phenomenon. Coombs appeared to uncritically accept factor analysis as a guaranteed method of psychological measurement; and the general thrust of his arguments suggests he felt a need to 'square' his theory of unfolding with factor analysis. The inherent weakness in the argument of factor analysis as psychological measurement is that an infinite number of sets of factor loadings and Z scores can be produced such that the basic factor analysis model (Equation 3) is satisfied. It is thus impossible to logically argue that any orthogonal factorial solution obtained out of the infinite number of such solutions comprises the ‘true’ solution. Moreover, Equation 3 does not present arguments as to exactly how many factors will present in any given solution. All it argues is that there will be \( n \) such factors for any finite, countable \( n \). Hence it is also impossible to ascertain the ‘correct’ number of factors out of the great many possible. Thus the conclusion that
in any factorial solution there exists an irreducible degree of arbitrariness cannot be avoided. Coombs did not discuss these inherent problems faced when arguing that factor analysis constitutes a genuine method of psychological measurement. These very problem of inherent arbitrariness in the factor analysis model casts doubt upon the theoretical plausibility of Coombs’s (1964, 1975) arguments concerning the ‘semihypersphere’ preference space as it logically entails that such spaces are also inherently arbitrary.

A more tenable and parsimonious explanation than that given by Coombs (1964, 1975) has been advanced by van Schuur & Kiers (1994). They argue that Equation 3 is a linear additive model and as such assumes an underlying cumulative or monotonic response process. This is indeed a true observation. They argue that factor analysis is thus simply unsuited to unfolding data given that the response process underlying such data is assumed to take the form of a single peaked preference function (Coombs & Avrunin, 1977) rather than a simple cumulative function.

Van Schuur & Kiers (1994) obtained ratings data conducted upon a set of eight candidates from the 1980 United States presidential election. The ratings obtained for each candidate lead to the unfolding of a single dimension of ‘conservatism/liberalism’. The correlation matrix of the ratings data was then calculated in which the rows and columns were ordered in a manner corresponding to the order of the candidates upon the unfolded dimension. They found an interesting pattern of high positive correlations along the diagonal (the diagonal of course consisting of values of 1), decreasing correlations down and to the left, and negative correlations in the bottom left hand corner. Decomposing this matrix using principal components analysis with Varimax orthogonal rotation, van Schuur & Kiers found an additional, ‘extra’ factor. Inspection of the factor loading tables revealed that the second factor was not a ‘utility’ factor proposed by Coombs (1964, 1975) and Coombs & Kao (1960). The ‘extra’ factor was comprised of the high positive loadings of the ‘conservative’ candidates whilst the first was comprised of the high positive loadings of the ‘liberal’ candidates. Two of the conservative candidates displayed small negative loadings upon the first factor and two liberal candidates displayed the same pattern upon the second factor. Van Schuur & Kiers concluded that:

The extra factor phenomenon is most dramatic when the unfolding representation is unidimensional, because the two-factor solution treats what in fact are the two halves of the
unfolding dimension as independent. Stated in general terms, the problem arises from using an inappropriate measurement model (p.107).

That is, by virtue of the pattern of coefficient magnitude and sign in the correlation matrix, the factor analysis method yields two factors, each of which are according to an unfolding analysis, either ends of the single unfolded dimension. Thus it can be concluded that the extra factor phenomenon is not a genuine substantive discovery that must be integrated theoretically with unfolding theory as attempted by Coombs (1964, 1975); but it is a trivial mathematical artefact of a cumulative statistical model applied to data generated by an underlying single peaked preference function.

The present study collected rating scale data from statements explicitly designed for analysis with Coombs’s (1964) theory of unidimensional unfolding. It can then be hypothesised that this data will give rise to the extra factor phenomenon as found by Coombs, (1964, 1975); Davidson, (1977); Green, (1988); Ross & Cliff, (1964) and Russell, (1980). It is further hypothesised that the findings will be consistent with the conclusions of van Schuur & Kiers (1994) in that the second factor phenomenon is an artefact of an inappropriate model.

To test the hypotheses, principal components analyses were performed upon the ratings data from each of the three versions of the Subjective Control scales. The ratings data from both the test and retest conditions were the subject of this analysis. To obtain the factor analytic criterion of simple structure (Kline, 1998), Varimax orthogonal rotation with Kaiser normalisation was undertaken. The analyses were performed using the SPSS for Windows, Version 10 computer package.

It was found that for each version of the Subjective Control scales under both test and retest conditions, the extra factor phenomenon was observed. Moreover, the pattern of factor loadings suggests that the findings were consistent with the conclusions made by van Schuur & Kiers (1994).

Table 5.15 displays the factor loadings and communalities for the rating scale data obtained for the general version of the Subjective Control scales under the test condition. Two discernible factors were found. The eigenvalue obtained for Factor 1 was 3.039 and that obtained for Factor 2 was 1.268. The factorial solution accounted for 71.78% of the variance in the ratings data. The item communalities ($h^2$) were high thus suggesting that the factorial solution adequately accounted for the variance in the ratings made to each statement (Kline, 1998).
Statements A and B loaded strongly onto the second factor with the loading magnitudes exceeding the minimum standard value of .3 (Kline, 1998). The remaining statements loaded heavily onto the first factor; with statements C, D and F loading negatively upon the second factor. Statements A and F both had strong positive loadings on their respective factors and strong negative loadings on the other factor. Inspection of the correlation matrix revealed the pattern similar to that found by van Schuur & Kiers (1994). Moderate positive correlation coefficients were found immediately under the diagonal with the exception of the correlation between statements B and C. Moving towards the bottom left corner of the matrix the coefficients became negative and increased in magnitude (see Appendix 19).

<table>
<thead>
<tr>
<th>Item</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>( h^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement A</td>
<td>-.524</td>
<td>.661</td>
<td>.711</td>
</tr>
<tr>
<td>Statement B</td>
<td>.168</td>
<td>.865</td>
<td>.773</td>
</tr>
<tr>
<td>Statement C</td>
<td>.804</td>
<td>-.141</td>
<td>.666</td>
</tr>
<tr>
<td>Statement D</td>
<td>.808</td>
<td>.181</td>
<td>.685</td>
</tr>
<tr>
<td>Statement E</td>
<td>.832</td>
<td>-.194</td>
<td>.730</td>
</tr>
<tr>
<td>Statement F</td>
<td>.635</td>
<td>-.581</td>
<td>.740</td>
</tr>
</tbody>
</table>

Table 5.15. Factor loadings & communalities for the general version – test condition

Table 5.16 displays the factor loadings and communalities for the general version of the Subjective Control scales under the retest condition. Two factors were again discovered supporting the results displayed in Table 5.15. The eigenvalue obtained for Factor 1 was 3.011 and that obtained for Factor 2 was 1.478. The factorial solution accounted for 74.80% of the variance in the ratings data. The item communalities (\( h^2 \)) were also high thus suggesting that the factorial solution adequately accounted for the variance in the ratings made to each statement.

<table>
<thead>
<tr>
<th>Item</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>( h^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement A</td>
<td>-.883</td>
<td>-.124</td>
<td>.795</td>
</tr>
<tr>
<td>Statement B</td>
<td>-.445</td>
<td>.749</td>
<td>.759</td>
</tr>
<tr>
<td>Statement C</td>
<td>.317</td>
<td>.799</td>
<td>.739</td>
</tr>
<tr>
<td>Statement D</td>
<td>.480</td>
<td>.647</td>
<td>.648</td>
</tr>
<tr>
<td>Statement E</td>
<td>.825</td>
<td>.321</td>
<td>.784</td>
</tr>
<tr>
<td>Statement F</td>
<td>.873</td>
<td>-.03</td>
<td>.764</td>
</tr>
</tbody>
</table>

Table 5.16. Factor loadings & communalities for the general version – retest condition

Interestingly, the pattern of factor loadings in Table 5.16 differed from that in Table 5.15. Statements C, D & E loaded strongly upon both factors. Statement A did not load
onto positively onto either factor. Inspection of the correlation matrix revealed that for each column the correlations were simply ordered. That is, the correlations decreased in positive magnitude then increased in negative magnitude towards the bottom of the matrix. This pattern was consistent with that found by van Schuur & Kiers (1994). Statement B also exhibited correlations of greater magnitude with the other statements than it did in the test condition.

Table 5.17 displays the factor loadings and communalities for the rating scale data obtained for the time involvement version of the Subjective Control scales under the test condition. Two discernible factors were found. The eigenvalue obtained for Factor 1 was 3.022 and that obtained for Factor 2 was 1.366. The factorial solution accounted for 73.14% of the variance in the ratings data. The item communalities ($h^2$) were high thus suggesting that the factorial solution adequately accounted for the variance in the ratings made to each statement.

<table>
<thead>
<tr>
<th>Item</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>$h^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement A</td>
<td>-.779</td>
<td>.253</td>
<td>.670</td>
</tr>
<tr>
<td>Statement B</td>
<td>-.270</td>
<td>.843</td>
<td>.784</td>
</tr>
<tr>
<td>Statement C</td>
<td>.483</td>
<td>.708</td>
<td>.735</td>
</tr>
<tr>
<td>Statement D</td>
<td>.821</td>
<td>.239</td>
<td>.731</td>
</tr>
<tr>
<td>Statement E</td>
<td>.844</td>
<td>.147</td>
<td>.734</td>
</tr>
<tr>
<td>Statement F</td>
<td>.846</td>
<td>-.139</td>
<td>.735</td>
</tr>
</tbody>
</table>

Statements A and B loaded positively onto Factor 2 and negatively upon Factor 1. Statement A’s loading upon Factor 2, however, did not exceed the minimum standard of .3 (Kline, 1998). Statement C ‘cross loaded’ strongly and positively upon both factors. This is interesting as this statement is located towards the ‘middle’ of the continuum. Statements, D, E and F all loaded strongly and positively upon Factor 1 with F loading negatively upon Factor 2.

<table>
<thead>
<tr>
<th>Item</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>$h^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement A</td>
<td>-.783</td>
<td>.111</td>
<td>.626</td>
</tr>
<tr>
<td>Statement B</td>
<td>-.239</td>
<td>.865</td>
<td>.806</td>
</tr>
<tr>
<td>Statement C</td>
<td>.420</td>
<td>.762</td>
<td>.757</td>
</tr>
<tr>
<td>Statement D</td>
<td>.861</td>
<td>.181</td>
<td>.774</td>
</tr>
<tr>
<td>Statement E</td>
<td>.798</td>
<td>.253</td>
<td>.700</td>
</tr>
<tr>
<td>Statement F</td>
<td>.901</td>
<td>-.138</td>
<td>.831</td>
</tr>
</tbody>
</table>
Table 5.18 displays the factor loadings and communalities for the time involvement version of the Subjective Control scales under the retest condition. Two factors were again discovered supporting the results displayed in Table 5.17. The eigenvalue obtained for Factor 1 was 3.079 and that obtained for Factor 2 was 1.415. The factorial solution accounted for 74.90% of the variance in the ratings data. The item communalities ($h^2$) were also high thus suggesting that the factorial solution adequately accounted for the variance in the ratings made to each statement.

The pattern of factor loadings found in the retest condition (Table 5.17) supported that found in the test condition (Table 5.18). Statements A and B again loaded positively onto Factor 2 and negatively upon Factor 1, with A’s loading upon Factor 2 not exceeding the minimum standard of .3. Statement C again cross-loaded strongly and positively upon both factors. Statements, D, E and F all loaded strongly and positively upon Factor 1 with F loading negatively upon Factor 2.

Table 5.19 displays the factor loadings and communalities for the rating scale data obtained for the impulses to gamble version of the Subjective Control scales under the test condition. Two discernible factors were found. The eigenvalue obtained for Factor 1 was 2.568 and that obtained for Factor 2 was 1.809. The factorial solution accounted for 72.95% of the variance in the ratings data. The item communalities ($h^2$) were high thus suggesting that the factorial solution adequately accounted for the variance in the ratings made to each statement.

<table>
<thead>
<tr>
<th>Item</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>$h^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement A</td>
<td>-.855</td>
<td>.133</td>
<td>.749</td>
</tr>
<tr>
<td>Statement B</td>
<td>-.282</td>
<td>.819</td>
<td>.751</td>
</tr>
<tr>
<td>Statement C</td>
<td>.121</td>
<td>.864</td>
<td>.761</td>
</tr>
<tr>
<td>Statement D</td>
<td>.560</td>
<td>.581</td>
<td>.651</td>
</tr>
<tr>
<td>Statement E</td>
<td>.809</td>
<td>.297</td>
<td>.743</td>
</tr>
<tr>
<td>Statement F</td>
<td>.841</td>
<td>-.128</td>
<td>.723</td>
</tr>
</tbody>
</table>

Statements A and B loaded negatively upon Factor 1 and positively upon Factor 2. Similar to the results for the time involvement version, Statement A’s loading upon Factor 2 did not surpass the minimum standard value of .3 (Kline, 1998). Statement C also loaded positively upon Factor 2. Statement D cross-loaded almost evenly onto both factors. Statements E and F loaded strongly and positively upon Factor 1, with statement F loading negatively upon Factor 2.
Table 5.20 displays the factor loadings and communalities for the impulses to gamble version of the Subjective Control scales under the retest condition. Two factors were again discovered supporting the results displayed in Table 30. The eigenvalue obtained for Factor 1 was 2.692 and that obtained for Factor 2 was 1.664. The factorial solution accounted for 72.60% of the variance in the ratings data. The item communalities (\(h^2\)) were also high thus suggesting that the factorial solution adequately accounted for the variance in the ratings made to each statement.

<table>
<thead>
<tr>
<th>Item</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>(h^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement A</td>
<td>-.856</td>
<td>.072</td>
<td>.737</td>
</tr>
<tr>
<td>Statement B</td>
<td>-.272</td>
<td>.832</td>
<td>.766</td>
</tr>
<tr>
<td>Statement C</td>
<td>.198</td>
<td>.835</td>
<td>.735</td>
</tr>
<tr>
<td>Statement D</td>
<td>.578</td>
<td>.573</td>
<td>.663</td>
</tr>
<tr>
<td>Statement E</td>
<td>.809</td>
<td>.244</td>
<td>.713</td>
</tr>
<tr>
<td>Statement F</td>
<td>.857</td>
<td>-.082</td>
<td>.741</td>
</tr>
</tbody>
</table>

The pattern of factor loadings found in the retest condition (Table 5.20) supported that found in the test condition (Table 5.19). Statements A and B again loaded positively onto Factor 2 and negatively upon Factor 1, with A’s loading upon Factor 2 being even smaller than in the test condition. Statement C loaded positively again upon Factor 2. Statement D again cross-loaded strongly, positively and almost evenly upon both factors. Statements E and F loaded strongly and positively upon Factor 1 with F loading lightly and negatively upon Factor 2.

The results of the principal components analyses are consistent with the findings of van Schuur & Kiers (1994); Davidson, (1977); Green, (1988); Ross & Cliff (1964); and Russell (1980). In each solution for each of the three versions of the Subjective Control scales, two factors emerged as predicted by Coombs & Kao (1960) and Coombs (1964, 1975). Furthermore, the pattern of coefficient magnitude and sign discovered in the correlation matrices was consistent with the findings of van Schuur & Kiers (1994). This suggests that the conclusion made by van Schuur & Kiers (1994) is plausible. The factor analysis model is not suited to analysing rating scale data which has been derived from a study involving the theory of unidimensional unfolding (Coombs, 1964); as the correlation matrices such data gives rise to contain a unique pattern involving both positive and negative correlations.
5.7 Discussion and conclusions

The aims of the study were fourfold. The first was to determine the unidimensional nature of the attribute of subjective control. The second was to test the attribute for additive structure using the theory of axiomatic conjoint measurement (Luce & Tukey, 1964). The third was to derive a scaling solution for each of the three questionnaires employed. The fourth was the investigation of the validity and reliability of each of the questionnaires.

The results of the present study support the argument made in Chapter 4 that the psychological attribute of subjective control is defined upon a continuum of necessary conscious exertion to regulate appetitive behaviour. This suggests a theoretical revision of subjective control. Conceptual deliberations upon the attribute perhaps should move away from dispositional trait arguments and toward hypotheses of latent properties of the mind. Thus psychometric investigations of subjective control do not need to make the argument that statements are the operational definitions of the attribute. Thus the conceptual problems associated with operationism mentioned in Chapter 2 can be avoided.

The range of the continuum of subjective control was defined by the ordinal determinables from no experience of the need to consciously exert regulation (Statement A) to the impossibility of exerting regulation despite conscious effort (Statement F). For each version of the Subjective Control scales, Statement A was nominated by 54% and 49% of the student and in situ club participants, respectively, as their preferred statement. This finding suggests two things. Firstly, it strongly supports the suggestion made by Heather et al (1993) in their development of the alcohol ICS that future impaired control apparatus include items similar to Statement A. Secondly, that those people who gamble regularly or occasionally and who do not experience problems with their gambling do not need to consciously exert control over their behaviour. These people can simply initiate and terminate a session of gambling as they please.

However, the data of the present study did not behave quite as expected. The data yielded a Coombs’s (1964) scaling solution that was very different to the scaling solution hypothesised on the basis of shared statement predicates. Perhaps the most striking finding of the study came from the departure from the predicted I scale dominant path. Michell’s (1994a, 1998) theory of the ordinal determinable predicts the asymmetric and transitive relation $D$ holding over a class of statements will result in preference orders forming a particular dominant path. This path is predicted solely on Michell’s argument
that the number of shared predicates between two adjacent statements (such as A and B) determines the magnitude of the interstimulus intervals between such statements. That is, all ordered metric information yielded by Coombs’s theory concerning the statements is governed by the statements’ constituent predicates and the logical relations holding between them.

As such, it was hypothesised that the interstimulus distances between statement A and the rest of the statements in all three questionnaires would be the greatest by virtue of A’s sharing only one predicate with all the others (the bifurcated tautologous predicate). The participants, however, judged the statements in the time limit and general questionnaires in an opposite manner such that the interstimulus distances between statement F and all other statements were of the largest magnitudes. They judged A to be similar to B whilst the interstimulus distance between B and C was as hypothesised. Moreover, interstimulus distances increased between the other statements as preferences moved away from A and towards F, forming a simple order upon the distances such that \( AB < BC < CD < DE < EF \); opposite to that which was predicted.

This departure of the preference orders made by participants from the preference orders predicted by the ordinal determinable led to the following interpretation. It appears that participants did not seem to judge interstimulus distances only on the shared semantic content of the predicates of the statements. Michell (1998) mentioned that all other things being equal, the ordered metric information of the quantitative J scale will be determined by the statements’ constituent predicates and the logical relations holding between them. In the case of the present study, this ceteris paribus clause may not have stood. Michell argued that a strong potential influence over the ordered metric information predicted by an ordinal determinable is the specificity of the predicates. Michell argued that the prediction of ordered metric information from the number of shared predicates only follows if the specificity of the predicates involved is the same for all predicates in the ordinal determinable. It may have been that in the present study, the participants’ perceptions of the specificities of the predicates differed from the researcher’s perceptions of them.

An instance of problematic predicate specificity may have existed within the Subjective Control scale of control over time spent gambling. It was found that for this version of the scales a partial order existed upon the interstimulus midpoints; although this partial order was not found in the re-test condition. The midpoints which could not be simply
ordered were all bounded by $I$ scales that had as the preferred statement either Statements D or E (see Figure 5.12). This may reflect a problem with the construction of these two statements.

Statement D contained the predicate *it is relatively difficult for me to limit the time I spend gambling*. Statement E contained the same predicate in addition to *it is very difficult for me to limit the time I spend gambling*. It was judged by the researcher that this latter predicate was at least as specific as the former predicate; and so hence the ordered metric information that would be obtained empirically would be that which was predicted on the basis of shared predicates. That this did not happen suggests the semantic intuition (Michell, 1998) of the researcher differed from that of the participants. It may have been that participants had difficulty in assessing the specificities of these predicates relative to one another. It is not obvious that the term *very difficult* indicates a greater degree of difficulty than does the term *relatively difficult*. This latter term by itself may have presented a problem of ambiguity to participants.

This and other unidentified problems concerning the specificity of predicates may have resulted in the observed ordered metric information being different from what was predicted. Michell (1998) warned that this was a potential problem, but one that was essentially unavoidable. A potential starting point for future research would be to administer the Subjective Control scales again to see whether the findings of the present study could be replicated. If the ordered metric information found in such a study is exactly that of the present study, it would strongly suggest that there is a problem with the specificity of the predicates in the Subjective Control scales. Further research concerning other predicates would need to be undertaken and revisions to the binary tree structures of the predicates would also need to be made to accommodate new predicates. Of course, the new scales would then be subject to extensive pilot testing.

Interestingly, the diversion between the predicted and observed ordered metric information satisfied a traditional psychometric diktat set down by L.L. Thurstone (1959, cited in Andrich, 1989):

If the scale is to be regarded as valid, the scale values of the statements should not be affected by the opinions of the people who help to construct it. This may turn out to be a severe test in practice, but the scaling method must stand such a test before it can be accepted as being more than a description of the people who helped construct the scale.

In a traditional psychometric terms, the discrepancy between the predicted and observed ordered metric information was a valuable finding, as it clearly demonstrated
that the obtained scaling solution was not an artefact of the scale constructor’s opinions and prejudices. Typically, psychometric items are either drawn from item banks or are derived from qualitative note-taking data collected by the scale constructor during the course of focus interviews with members of criterion groups (such as club gamblers, on-course horse racing gamblers and problem gamblers). Statements constructed using the theory of the ordinal determinable, however, are explicitly the creations of the scale constructor. This fact could lead to the allegation that statements derived in this manner describe the investigator and not necessarily anyone else. Hence that in the empirical test of statements generated by an ordinal determinable, a discrepancy between the predicted and observed scaling solutions may actually enhance the validity of the questionnaires through nullifying this particular accusation.

Of course, the description of any psychological attribute, state or trait would consist of much more information than that available using the highly restricted set of statements employed in this study. It was possible that the predicates selected for use in this study did not contain enough semantic information to allow a thorough description of the attribute. Initial pilot testing of the draft questionnaires did discover problems with certain predicates which were either discarded or reworded. Yet the pilot tests on the final versions did not find further fault with the predicates. If it was simply that the data obtained was a result of inappropriate predicates, a dominant path may not have resulted given the variety of different preference orders that may have arisen. This may have applied to statements D, E and F in particular as these items explicitly stated that low control over gambling was ‘causing problems’. Certainly the meaning of the predicate “causes problems” is very broad and open to the personal experiences and prejudices of the individual. It would have been likely that if this predicate was inducing responses which strongly reflected individuals’ idiosyncrasies, the statements would not have been ordered along a single continuum. Preference orders, however, of these particular statements exhibited a great deal of unidimensional structure.

Moreover, it was unlikely that this departure was due to chance. The dominant paths discovered in the test data of all three questionnaires were supported in the data of the retest questionnaires. This suggests that the departure was a robust finding. Additionally, paired comparison error rates remained stable across the test – retest phases. More errors were made in the retest phase, however, this difference was not statistically significant.

The effect of context in the presentation of the questionnaires is another plausible explanation for the departure of the dominant paths from those predicted. It could be that
the paths found in this study were resultant of the presentation of the statements in each of the questionnaires. In each questionnaire, the statements were presented in the alphabetical order A, B, C, D, E, F. Thus it was possible that participants perceived additional ordering information from the order of presentation, which then could have affected participants’ preference orders. Thus the discovered dominant paths may actually be artefacts of order bias. Johnson (2001), however, found that attitude statements constructed using Michell’s (1994, 1998) theory of the ordinal determinable were context invariant, as opposed to statements not so constructed. When six statements were presented in the orders D B C E F G and A B C E F G, rank orderings did not collapse nor did greater intransitivity of paired comparison tasks result (Johnson, 2001). Such effects with statements constructed ordinarily did occur. Thus it is implausible that the statements in the current study were affected by context variation.

With the exception of the time involvement version, the dominant I scale paths found in this study (as shown in Figures 5.10 to 5.15) led, as predicted by Coombs (1964) to a simple ordering upon the interstimulus midpoints. Such an ordering on the midpoints can reduce the midpoint data to a special form of axiomatic additive conjoint measurement (Michell, 1998). The satisfaction of the algebraic double cancellation axiom (Thomsen condition, Krantz et al, 1971) by the strict simple orders of the midpoint data from each of the three questionnaires (Figures 5.16 & 5.17) provides limited evidence in support of subjective control being genuinely quantitative. This finding is consistent with two hypotheses. Firstly, that the intervals between the elements of a psychological preference space are quantitative. Secondly, that Coombs’s (1964) theory of unidimensional unfolding is a true theory of such preference spaces. Moreover, it suggests that the scale values derived from Goode’s algorithm (Goode, 164, cited in Coombs, 1964) were actual, real-valued measurements unique up to positive linear transformations. That these values were derived from purely ordinal relations in the observed data is in contrast to classical test theory where participants’ numerical responses to tests are justified as interval scale measurements on a purely practical basis (Lord & Novick, 1968). The patterns of double cancellation found are those indicated as Pattern 1 and Pattern 3 in Michell’s (1990, p.105) table of double cancellation patterns. Pattern 1 held for the data from the general questionnaire whilst Pattern 3 held for the impulses questionnaire. Thus both patterns held for the data from the time involvement questionnaire.

Nevertheless, as a method of psychological scaling Coombs’s theory was limited in the present study by the use of six statements. There are 286 distinct I scale descending paths
through Figure 5.8 and of these only 118 do not satisfy the cancellation conditions of conjoint measurement. Thus the probability that a randomly chosen dominant $I$ scale path will satisfy axiomatic conjoint measurement is .5874 (Michell, 1994a). This in itself is then not an especially powerful test of additivity. Events that have a probability of .5874 are not unlikely. If it is argued that the test and retest conditions constituted independent trials, then the probabilities of satisfying conjoint measurement can be multiplied yielding a final probability of .345. An event with a probability of .345, however, is still not unlikely.

There is, however, a strong counter to this argument. Consider the $a$ priori probability of obtaining exactly the same dominant path twice. If the underlying structure was merely ordinal, then it follows that all participants should have given an $I$ scale that was a folding of the qualitative $J$ scale around their points of maximum preference. In this instance, however, no specific dominant path is entailed. It thus means that responses on bilateral triples may be effectively random since there is no ordered metric information to determine them. If this is so, then the likelihood of observing exactly the same dominant path is very small, a figure approaching $1/286^2$. Thus, the fact that the dominant paths were observed in the re-test condition and that the midpoint orders satisfied double cancellation can be interpreted as supporting the hypothesis that the attribute of subjective control is quantitative.

It cannot be discounted, however, that memory effects influenced the finding of the same dominant $I$ scale paths in the re-test condition. Importantly, the retest phase of questionnaire administration was done with participants remaining in situ after completing the test phase. This was done for the practical reason that it would be impossibly difficult to encourage the in situ club gamblers and the self-referred problem gamblers to undertake the retest phase at a date sometime after the initial test phase. The key disadvantage of this procedure, however, is that it was more likely that participants would remember the responses they made during the test condition when they were undertaking the re-test condition. Often the re-test condition is performed several days or a week after the test condition. For the present study, the very difficult practical problems mentioned above rendered such an interval of time between conditions impossible.

In recognition of this limitation, a ‘filler task’ in the form of the administration of the two versions of the SGC (Baron, et al, 1995) was undertaken between the test and retest
phases. Filler tasks are used extensively in cognitive psychology and have demonstrated to be highly efficient in removing residual memory traces of the prior task in short term memory (Best, 1995). Additionally, all participants were verbally instructed not to look at the responses made in the test phase. Thus the first booklet remained closed during the retest phase. It is possible that the filler task mitigated the effect of memory upon participants’ responses made in the re-test condition. The extent of such mitigation, however, is not easily ascertained. Future research upon the Subjective Control scales should endeavour to employ greater periods of time between test and re-test conditions. This is perhaps the best way of assessing the influence of memory effects upon responses made in the re-test condition. Such research, however, may encounter strong practical difficulties.

The Subjective Control scales displayed only a low level of criterion validity. The $I$ scale values of the Subjective Control scales were moderately correlated with frequency of gambling play and expenditure per session (Tables 5.10 & 5.11). To estimate the variance accounted for in the criterion variables by the $I$ scale values, the square values of the coefficients were calculated. This revealed that less than 25% of the variance was accounted for by participants’ $I$ scale values. This perhaps means that the predictive capacity of the Subjective Control scales is rather poor. It is highly probable, however, that the correlation coefficients may have been confounded by the $I$ scale values being non-stochastic measurements without dispersions. The lack of variation thereof may have lead to an underestimation of the strength of the relationship between participants’ $I$ scale measurements and the criterion variables. Subjective retrospective reports of amount spent gambling, however, have been found to be greatly error prone (Blaszczynski, Dumla & Lange, 1997). Thus reported session expenditure may not constitute a reliable criterion variable.

The coefficients displayed in Tables 5.10 & 5.11 were, however, in the appropriate positive direction and were highly statistically significant. This perhaps suggests that participants in this study who measured higher on the Subjective Control scales also tended to gamble frequently and to spend larger amounts of money within a session of play. Higher frequencies of gambling and higher expenditures per session are reliable, ‘hard’ indices of greater involvement in gambling, with problematic gamblers typically exhibiting a very high frequency of play and great levels of expenditure per session (Dickenson, 1991). Future research could entail a replication study within which participants could record their frequency of gambling and session expenditure. If only
moderate correlations were found again, two plausible interpretations could be made. Firstly, that the predictive validity of the Subjective Control scales is problematic. Secondly, that the non-stochastic nature of the I scale measurements confounds the calculation of product moment correlation coefficients. Further research would then have to be conducted to ascertain which of the above interpretations is the most plausible. It would be apt for such research, however, to investigate the use of additional criterion variables.

The I scale values of the Subjective Control scales were strongly positively correlated with both versions of the SGC (Baron, et al., 1995) (Tables 5.12 & 5.13). Moreover, these correlations were also highly significant. Calculating the square of these coefficient values found that between approximately 48 to 69% of the variance in SGC scores was accounted for by the measurements of the Subjective Control scales across test and retest conditions. This suggests that the Subjective Control scales exhibit strong concurrent validity with the only other independently constructed subjective control scale. This strongly suggests that both the SGC and the Subjective Control scales are assessing the same unidimensional attribute.

The Subjective Control scales also displayed good clinical discriminative validity. At least two thirds of participants with a SOGS (Lesieur & Blume, 1987) cut off score greater than 10 gave either statement E or F as their preferred statement in each of the three versions of the Subjective Control scales. This indicates that the Subjective Control scales have the capacity to accurately identify participants, who were separately clinically diagnosed as problem gamblers, as experiencing great or extreme difficulty controlling their gambling. Moreover, the modal I scale values of these participants were the highest possible values of the Subjective Control scales. Thus the scales may have some practical utility in aiding the assessment of individuals presenting themselves for treatment of their gambling behaviour.

In regards to the assessment of construct validity, factor analyses were performed upon the rating scale data. The results, however, strongly supported the findings of previous research (Davidson, 1977; Green, 1988; Ross & Cliff, 1964; Russell, 1980; and van Schuur & Kiers, 1994) in that two factor simple structure solutions were found for each questionnaire version instead of the single factor solutions expected for purely unidimensional attributes.

The item correlation matrices found in the present study reflected those found in previous research in that a unique pattern involving both positive and negative
coefficients was present. Factor analysis assumes that for any unidimensional attribute, a correlation matrix involving those items which ostensibly measure that attribute will contain only positive coefficients. Thus it can be safely concluded that factor analysis is an inappropriate statistical technique to model rating scale data derived from a study involving unidimensional unfolding, as item correlations will not behave as the factor analysis model expects.

The present study, however, differed greatly in one respect from previous research which has investigated the relationship between factor analysis and the theory of unidimensional unfolding (Coombs, 1964). The present research found that the independence and double cancellation axioms of conjoint measurement (Luce & Tukey, 1964) were satisfied in the unfolding of participants' I scale data. By virtue of their algebraic nature these axioms present what is arguably the most rigorous test of unidimensionality in the quantitative behavioural sciences. In the present study, however, the results of the principal component analyses contradicted the conjoint measurement results in that two factors were found instead of one. This result is very problematic for factor analysis if the technique is argued to be both a genuine method of psychological measurement and a reliable means of detecting unidimensional attributes. The findings of the present study support the interpretation that factor analysis is incapable of detecting all possible unidimensional psychological attributes; and that it contradicts axiomatic conjoint measurement. If replicated empirically, this contradiction would constitute strong evidence against the argument that factor analysis is a genuine method of psychological measurement.

The results of the present study suggest that further development of the Subjective Control scales could be benefited in several ways. The difference between the hypothesised and discovered ordered metric information suggests that the scales be administered to several groups of participants perhaps in the manner of Baron et al (1995). This relatively straightforward test of the ordered metric structure of the scales would quickly reveal either the triviality or significance of the present findings.

The method by which the theory of axiomatic conjoint measurement (Luce & Tukey, 1964) was applied in the present study could also be improved. The testing of the scales for additive structure could be greatly improved by testing the higher order condition of triple cancellation (Krantz, et al, 1971). This, however, would require the very difficult task of constructing ordinal determinables which lead to the creation of the necessary minimum of eight statements. Such construction would entail the use of more predicates,
possibly leading to even more highly stilted and contrived forms of statement expression. Predicate specificity may also be another potential source of difficulty.

These problems, however, are not insurmountable. Future research with eight statements could provide much more powerful information concerning the quantitative structure of subjective control than that presented in the current study. The number of dominant I scale paths for eight stimuli, however, is an unknown figured estimated to be in the millions. The number of such dominant paths satisfying either double or triple cancellation is also unknown except of course that any path which satisfies triple cancellation would also satisfy double cancellation. Thus it is not possible at the present time to calculate the exact chance probability of satisfying either double or triple cancellation in the case of eight statements.

It was noted earlier that relative to the other two samples of participants, the data from the self-referred problem gamblers exhibited a large amount of error. As this latter group was not administered the questionnaires by the investigator but by gambling counsellors, this error perhaps suggests an improvement in questionnaire administration. These participants may have found the bilateral paired comparison tasks difficult to understand and the instructions confusing. It could be made easier for these participants by administering the full set of 15 paired comparisons with simple instructions. Another improvement could be for the investigator to administer the questionnaires. This, however, could encounter ethical concerns given that these participants are very likely to be recruited from specialist treatment clinics as they were in the present study.

An aforementioned potential source of variation was the statement predicates themselves. A possible method of improvement would be the revision and alteration of these predicates. This approach, however, would require re-commencing the research process with pilot studies and perhaps would only be undertaken after the above avenues of scale development were exhausted.

In conclusion, three versions of the Subjective Control scales were constructed to assess control over gambling in general terms, control over time spent gambling and control over urges to gamble. These scales were constructed using Michell’s (1994a, 1998) theory of the ordinal determinable. Analysing the paired comparison and ranking data with respect to Coombs’ (1964) theory of unidimensional unfolding, it was found that the ordered metric information satisfied the axioms of additive conjoint measurement (Luce, & Tukey, 1964). This finding was consistent with the hypotheses that subjective control is a quantitative attribute and that Coombs’ (1964) theory of unidimensional unfolding is
a genuinely quantitative theory of preference. It was also found that principal components analyses of the rating scale data resulted in two factor solutions. This supported the results of previous research with respect to the extra factor phenomenon (Coombs, 1964, 1975; Coombs & Kao, 1960; van Schuur & Kiers, 1994); suggesting that factor analysis has a limited capacity to detect unidimensional attributes as it is not suited to analysing unfolding data.
Chapter Six: Measurement via observed probabilities of item response: Item Response Theory (IRT) probabilistic models of Coombs’s (1964) theory of unidimensional unfolding.

Chapter Four traced the conceptual development of subjective control and its role in the behaviours of alcohol consumption and gambling. It was argued that the concept had hitherto been assumed to be quantitative and that attempts to measure the attribute reflected this. Subjective control, it was argued, had not been adequately defined and that a better definition was needed. To this end, a new definition of subjective control was proposed towards the end of Chapter Four. This definition argued that subjective control was an attribute of the mind – a single dimension of conscious deliberation upon the engagement of the self in the behaviours Orford (1985, 2001) termed appetitive. This was not an operational definition nor was it an argument for the existence of a dispositional trait.

The previous chapter contained an attempt to measure the concept, employing this alternative definition as the substantive basis for the construction of statements. In so doing the Subjective Control scales were devised. But this attempt at the measurement of subjective control was quite unusual. It employed a deterministic theory of preference behaviour (viz., Coombs, 1964) to arrive at a scaling solution for each of the Subjective Control scales. Thus the measurements derived (unique up to linear or affine transformations only) for both the persons and statements were argued to be non-stochastic. To add to this peculiarity, Coombs’s (1964) theory of unidimensional unfolding was itself tested as a quantitative theory of preference through the use of an axiomatic theory of measurement from the field of mathematical psychology. This axiomatic theory was that known as simultaneous, additive conjoint measurement (Luce & Tukey, 1964; Krantz, et al, 1971).

Mathematical psychology, however, is but one school of thought within quantitative psychology. Moreover, it is the school in the minority position. The other school is generally known as psychometrics. Psychometrics itself can arguably be thought of as consisting of three spheres. The first of these is classical test theory (Lord & Novick, 1968). This is the sphere that has traditionally formed the theoretical base of psychometrics. The second sphere relates to a particular statistical technique of scale construction. This is the sphere of the matrix method of factor analysis (Spearman, 1904), but it has also recently incorporated structural equation modelling (SEM). This sphere is the most popular as factor analysis is the most widely used technique of scale
construction. Adherents of this school are known as factor analysts and include such psychometricians as Harman (1976), Kline (1986, 1998) and R.B. Cattell (1978). The third sphere is item response theory (IRT) (van der Linden & Hambleton, 1997). This sphere is also referred to as latent trait theory (LTT) (Andrich, 1988a).

Of these three spheres, IRT is the one rapidly gaining ascendancy over the others (Embertson, 1996). The rise of IRT is reflected in the research literature. Even the most casual perusal of a recent volume of psychometrics' flagship journal *Psychometrika* will reveal the majority of articles investigating some aspect of IRT. This is in contrast to a volume of the same journal 30 years ago which typically would have consisted of several articles on factor analysis. Even the late factor analyst Kline (1998) suggested that IRT could supplant factor analysis in the near future.

The two schools of mathematical psychology and psychometrics are diametrically opposed to one another philosophically. The representational theory of measurement (Krantz, et al, 1971; Suppes & Zinnes, 1963) is dominant within mathematical psychology. The school posits 'concrete' objects and events possess many kinds of surface structures. Surface structures that are measurable will exhibit homomorphisms into the real numbers. Not all surface structures, however, are capable of this. Measurable surface structures are identified by investigating the behaviour of the automorphisms those structures give rise to. The principal empirical endeavour of mathematical psychologists is to find surface structures of objects and events whose sets of automorphisms form Archimedean ordered mathematical groups of translations under function composition (Luce, 1986, 1987, 2001). Such groups will be found if and only if the behaviour of the automorphisms accord with a particular set of axioms. This set of axioms is that given by Hölder (1901).

In contrast, psychometrics argues of the existence of quantitative, latent continua within the human mind. These continua are not directly observable, however, and psychometrics typically advances operational definitions of these continua. These operational definitions are almost always the observed responses made to particular psychometric tests. These observed responses are often either test scores or ratings. The key concern of psychometrics is the fitting of various statistical models to such observed data. A model is argued to have explained the data if the model fits the data well according to pre-specified criteria.

Arguably the most important philosophical distinction between psychometrics and mathematical psychology rests with the vexatious issue of error. Mathematical
psychology does not propose formal theories of the behaviour of errors. Instead it shares a similar perspective towards error with the natural sciences. It considers error to be unavoidable (Luce, 1995, 1997b) but it importantly considers that there are many potential sources of error. Errors are noted and recorded in an empirical study, however, they do not play a formal role in the thinking of mathematical psychologists. Errors are of concern if they suspected to have confounded the testing of axioms. Error can falsely demonstrate either the satisfaction or non-satisfaction of any particular axiom. If error confounds the testing of an axiom in a given empirical situation, then mathematical psychologists will tend to focus on developing better ways to control error. An example of an attempt to obtain better stimulus control in relation to the construction of attitude statements is Michell's (1994a, 1998) theory of the ordinal determinable.

The philosophy of mathematical psychology towards error was reflected in the empirical component of the previous chapter. Participants' intransitive paired comparisons were counted individually as errors as were any individual paired comparison task not responded to. Overall error rates and error rates for each group of participants were also calculated. It was found that the number of such errors was low compared to the number of transitive paired comparisons. Furthermore, formation of I scale dominant paths satisfied the single cancellation or independence axiom of axiomatic conjoint measurement (Michell, 1990). Dominant paths were formed in both the test and retest I scale data for each of the three Subjective Control scales, strongly suggesting that the satisfaction of the single cancellation axiom was not trivial. Additionally, these data also satisfied the double cancellation (or Thomsen condition) axiom. Therefore it can be safely argued that the error found in the paired comparisons did not confound these axioms. Hence the number of such errors was presented but they were not further evaluated.

In contrast, psychometrics considers error formally in all its arguments. Classical test theory completely formalised the role of error with the work of Lord & Novick (1968). The basic equation of classical test theory asserts that an observed score is the sum of an error score and an unobservable 'true' score; with error being normally distributed with a mean of zero and standard deviation of one. IRT also considers error formally but does so within the pertinent statistical models. Errors have dispersions but the distributions can either be logistic or normal, depending on the model. Importantly, psychometricians believe that the respondent is a principal source of error in test score and rating data. This is probably true, however, psychometricians appear to consider that error from this
source cannot be mitigated. Indeed, Lord & Novick (1968) appear to believe that error is as an important attribute of human psychology as the hypothesised latent ‘true’ scores.

Psychometricians such as Cliff (1992) have argued that the problem of error has prevented mathematical psychology from having a great theoretical and methodological impact upon quantitative psychology. In response to Cliff (1992), Narens & Luce (1993) concede that error is a problem for mathematical psychology. Mathematical psychologists, however, have made their own criticisms of psychometrics. They have criticised psychometricians for assuming that statistical models fitted to a body of data are valid theories of human psychology (Krantz et al, 1971). Luce (1988) has called this inference of psychological structures from statistical models the ‘tools to theory hypothesis’. Luce (1997b) also argued that no definition of probability has yet been advanced which is fully satisfactory scientifically.

Both mathematical psychologists and psychometricians have raised important issues concerning psychological measurement. It is highly likely, however, that these issues will not be resolved for some time. Thus it is prudent for any quantitative psychologist to be cognisant of both schools and their respective strengths and limitations. So far this thesis has empirically explored scale construction from the perspective of the school of mathematical psychology. Hence the empirical research conducted thus far is of limited scope.

Given that the previous chapter used Coombs’s (1964) theory of unidimensional unfolding as a basis for scaling, it made good scientific sense to investigate potential probabilistic models of unfolding. It so happens that such probabilistic models do exist. These models originate from the sphere of IRT. Of these models, the class of probabilistic unfolding models proposed by the item response theorists Andrich (1988b, 1989, 1995, 1996, 1997) and Luo (1998, 2001) are of particular theoretical and empirical interest. Not only are the models proposed by these scholars applicable to a wide range of data, including paired comparisons and ratings, they bring an impressive unity to the otherwise diverse approaches of Thurstone (1928), Coombs (1950, 1964) and Likert (1932). That Andrich (1996) has been able to reconcile the works of these three scholars is an impressive achievement in its own right. An empirical investigation of some of these models may provide for an interesting comparison with the axiomatic work conducted thus far; and might provide fresh insight into the psychological mechanisms underlying preference behaviour.
Thus the aim of the present chapter was to subject the data gathered for the purposes of the previous chapter to probabilistic analysis via the IRT unfolding models proposed by Andrich (1988b, 1989, 1995, 1997) and Luo (1998, 2001). In order to theoretically locate these models this chapter also briefly outlines the wider psychometric field of IRT. The argument that Rasch’s (1960) simple logistic model is a probabilistic form of axiomatic conjoint measurement (Perline, Wright & Wainer, 1979) is also examined.

6.1 A Brief Overview of Item Response Theory

IRT is currently emerging as the dominant paradigm of psychometrics. This field’s endeavours concentrate on the statistical modelling of the probabilities of certain types of responses to psychometric items such as attitude statements and numerical problems. IRT hypothesises that the quantitative responses made by humans to psychometric items are formally related to the relevant, quantitative, latent continua via continuous mathematical functions (van der Linden & Hambleton, 1997). It is a general empirical aim of IRT to discover these functions. In so doing IRT supposes that at least some of the psychological processes which lead to the production of test scores or ratings can be characterised by continuous mathematical functions. IRT’s genesis is argued to be found in the work of the psychometrician L.L Thurstone (1928) and his law of comparative judgement (Andrich, 1988a).

The area of IRT has experienced steady growth since Thurstone. The Danish mathematician Georg Rasch (1960) proposed a simple logistic function to model the probabilities of responses made to dichotomous items. The logistic function

\[ y = (1 + \exp(-x))^{-\exp(x)} \]

has several desirable mathematical properties. It is the most parsimonious function available for modelling dichotomous responses (Ryan, 1983). It is the most convenient one to obtain a smooth increase from the probability of 0 (where \( x = -\infty \)) to 1 (where \( x = +\infty \)) (Hutchison, 1991). Most importantly, this function assumes for such response data a ‘closed form’ cumulative frequency distribution; and thus enables the theoretical probabilities of responses to be calculated algebraically from the single estimated model parameter (Train, 2002). This crucial property of the logistic function enabled Rasch to argue that both the items and the persons responding to the items could be measured on a single, relevant dimension via the estimation of the logistic function’s single parameter. The model has since been termed the Rasch simple logistic model and the concept of measurement within the parameter has been termed specific objectivity (Rasch, 1977).
Perhaps as a consequence of Rasch’s (1960) work on the reading abilities of school children, IRT has enjoyed its most significant empirical application in the area of human performance. The development of the two and three parameter logistic models from the basic one – parameter (or Rasch) model was done specifically to account for the effects of guessing and partial information upon responses made to items designed to assess performance across a wide range of abilities (Hutchinson, 1991). The additional parameters these models introduce to the simple logistic function violate Rasch’s (1977) concept of specific objectivity as the additivity within the single logistic model parameter does not solely govern the calculation of theoretical probabilities. Hence these models are argued not to be measurement models (Ryan, 1983). Although in a minority position within IRT because of the strict requirement of specific objectivity, adherents of the Rasch model argue that it draws considerable conceptual strength as a model of measurement from it being a probabilistic realisation of axiomatic conjoint measurement (Perline, Wright & Wainer, 1979).

The scope of empirical application of IRT started to expand in the late 1970’s and its growth has been especially strong during the past 20 years. Work began at this time on extending the Rasch (1960) model to incorporate responses made to items that employed Likert’s (1932) theory of summed ratings (Andrich, 1978). This heralded the arrival of IRT into a wider empirical realm of psychological assessment given the pervasive use of Likert’s procedure in such areas as attitude and personality measurement. Empirical work in such areas hitherto had been the sole domain of classical test theory (Lord & Novick, 1968) and the multivariate statistical procedure of factor analysis (Spearman, 1904). Already IRT has extended further into the area of attitude measurement with the recent development of probabilistic models of Coombs’s (1964) theory of unidimensional folding (Andrich, 1995, 1997; Luo, 1998, 2001; Luo, Andrich & Styles, 1998).

IRT is concerned principally with the responses made to each of the individual items that comprise a psychometric apparatus, rather than just the aggregate total scores that such items produce. It is these total scores (which are produced when subjects complete psychometric tests) that are of prime concern to classical test theory. Total scores are viewed by the propositions of classical test theory simply as additive compositions of subjects’ true and error scores (Lord & Novick, 1968). IRT is highly critical of classical test theory for this very argument. Ryan (1983) claims that in isolation, the total score contains insufficient information to order subjects upon the ‘substantive dimension’ or relevant psychological attribute. van der Linden & Hambleton (1997) state that as no
restriction is placed on the values total scores can manifest (that is, classical test theory cannot predict the occurrence of certain total score values for any particular test under any particular condition), an infinite number of sets of values for both true and error scores can be presented, such that their sums are equal to any particular observed total score. Examination of the basic proposition of classical test theory (Lord & Novick, 1968) reveals that the statement of van der Linden & Hambleton (1997) is indeed true.

IRT argues that of primary importance is the observed proportions (or relative frequencies) of each type of response each item is designed to elicit from those completing a test. The item response type most frequently used in IRT is the dichotomous one. That is, there are only two possible responses that can be made to such items. As a direct consequence of its empirical application to human performance, the dichotomous ordered response type most frequently used in IRT has been correct rather than incorrect. Dichotomous items however, are not necessarily restricted to use in human performance assessment and can be of the ordered kinds yes rather than no, accept rather than reject or agree rather than disagree.

In any case, it is understood theoretically (Andrich, 1988a) that dichotomous items can possibly elicit what is known as a random Bernoulli outcome variable. This kind of variable can only take the values of 0 and 1. As such, the proportions for each value of the Bernoulli outcome variable can be observed after the item has been administered to a sample of participants. As these proportions are necessarily bounded between the limits of zero and one, a statistical model can be constructed so as to predict the observed proportions with model parameters that necessarily have restricted ranges of values. It is possible to include amongst such parameters a person parameter. Thus the problem of trivial true score estimates associated with classical test theory is avoided and so hence IRT is argued to be more than a theory of psychometric test data (Andrich, 1988a).

6.2 The Rasch (1960) one-parameter logistic model

The genesis of Rasch’s (1960) work lies in the work of the psychometrician Thurstone (1928) and his famous ‘law of comparative judgement’ (Andrich, 1988a). This was not actually a law in the sense of an empirically derived equation but a hypothesis concerning the behaviour of responses made to paired comparison tasks (Michell, 1990). In such tasks a pair of stimuli is presented and subjects are simply instructed to select the stimulus within each pair that is the greater in some prescribed sense. Thurstone argued for the existence of a single continuous, unidimensional continuum upon which the
stimuli could be ordered. The locations for the two paired stimuli upon this continuum can be given by:

\[ \psi_x = \mu_x + \varepsilon_x \quad \text{and} \quad \psi_y = \mu_y + \varepsilon_y \]

where \( \psi_x \) and \( \psi_y \) are the ‘discriminal processes’ of the paired comparison stimuli \( x \) and \( y \), \( \mu_x \) and \( \mu_y \) are the ‘true’ locations of \( x \) and \( y \) or are the ‘modal discriminial processes’ (Thurstone, 1927) of \( x \) and \( y \) (Michell, 1990). The error terms \( \varepsilon_x \) and \( \varepsilon_y \) are independently and identically distributed normally with means of zero and with variances (or ‘discriminal dispersions’) \( \sigma^2_x, \sigma^2_y \), respectively (Bock, 1997; Michell, 1990; Yellott, 1977). The probability that \( x \) is chosen over \( y \) and vice versa is given thus:

\[ \Pr[x|x, y] = \Phi(\mu_x - \mu_y) = 1 - \Pr[y|x, y] \]

where \( \Phi(\mu_x - \mu_y) = \frac{1}{\sqrt{2\pi}} \int_{(\mu_x - \mu_y)} e^{-t^2/2} \, dt \)

where Eqn 3 is the normal distribution function of the differences between the mean discriminial processes values \( \mu_i \) for the paired comparison stimuli \( i = x, y \) (Bock, 1997; Yellott, 1977). From 1, 2 & 3 it follows that:

\[ z_{xy} = \mu_x - \mu_y \]

where \( z_{xy} \) is the standard normal score which can be obtained from the z-score table if the probability in Eqn. 2 is known (Michell, 1990). These standard scores form the scale values of the stimuli and Michell (1990) has explained how Thurstone’s theory can be tested using axiomatic conjoint measurement (Krantz, et al, 1971).

Rasch’s (1960) one parameter logistic model is essentially an extension of Thurstone’s theory (Andrich, 1988a). Rasch, in his studies on the reading abilities of Danish school children in the early 1950’s, found the probability that person \( \nu \) had \( a_{\nu} \) misreadings on a repeated oral reading test \( i \) was given by the Poisson distribution:

\[ \Pr[a_{\nu}] = e^{-\lambda_{\nu}} \cdot \frac{\lambda_{\nu}^{a_{\nu}}}{a_{\nu}!} \]

Of interest in this equation is the parameter \( \lambda_{\nu} \). The magnitude of this parameter determined the probability with which \( \nu \) made \( a_{\nu} \) errors. Rasch (1977) stated:

If the value of the parameter is 0 a result of no errors will occur with a probability of 1 while all other results have probabilities of 0. If the value of the parameter is small, the low number of reading errors will have large probabilities and high numbers have small probabilities; if the parameter value is high, the largest probabilities will be found at numbers in some neighbourhood of the parameter value (p.61).
Importantly, Rasch observed that the magnitude of this parameter was influenced by two factors. He noted that for any particular test \( i \), an excellent reader will make far fewer errors than would a poor reader and thus \( \lambda_{vi} \) would be low. A low parameter value would likewise result for any particular student \( v \) if that student read an easy test than a difficult one. Thus Rasch (1977, Eqn I:6, p.62) argued that \( \lambda_{vi} \) was the product of a ‘person’ parameter \( \beta_v \) and an ‘item difficulty’ parameter \( \delta_i \), such that:

\[
\lambda_{vi} = \beta_v \cdot \delta_i \quad 6
\]

As can be seen from Eqn 6, Rasch argued that if any particular reading test \( i \) was difficult, the item parameter \( \delta_i \) (which Rasch (1977, p.61) termed the ‘degree of difficulty of the test’) would be large thus increasing the size of \( \lambda_{vi} \), thus increasing the probability of the test being misread. Increasing the person parameter \( \beta_v \) would have the same effect upon \( \lambda_{vi} \) and Rasch termed this parameter ‘degree of reading weakness’ (1977, p.62). This Rasch termed the Multiplicative Poisson Model. In Rasch’s original exposition (1977, Eqn 6), a large magnitude of the person parameter \( \beta_v \), meant that the person \( v \) possessed a large degree of inability. To presumably make matters simpler, Eqn 6 can be changed so that large values of this parameter represent greater ability, not less:

\[
L_{vi} = B_v/D_i \quad 7
\]

where \( B_v \) is the location of the person \( v \) upon the latent trait; \( D_i \) is the location of item \( i \) upon the latent trait; and ‘\( \cdot \)’ is the multiplicative inverse relationship existing between them (Andrich, 1988a, p.25). Taking either the common or natural logarithms (in the Rasch model case, the natural) of both sides of Eqn 8 reduces the inverse multiplicative relationship to the additive inverse, such that:

\[
\ln L_{vi} = \ln B_v - \ln D_i \quad 8
\]

Eqn 6 is now transformed to read:

\[
\lambda_{vi} = \beta_v - \delta_i \quad 9
\]

where \( \ln L_{vi} = \lambda_{vi} \), \( \ln B_v = \beta_v \) and \( \ln D_i = \delta_i \) (Andrich, 1988a). Eqn 9 is simply Eqn. 7 expressed as a log metric. Introducing the right hand side of Eqn. 9 to the simple logistic function, the one – parameter or Rasch model for items takes the form:

\[
\Pr[x_{vi} = 1 | \lambda_{vi}, \delta_i] = \frac{e^{\beta_v (\delta_i - \delta_i)}}{1 + e^{\beta_v (\delta_i - \delta_i)}} \quad 10
\]
where \( x_n \) is a random Bernoulli outcome variable taking either 0 or 1 values and 
\[
e = \lim_{n \to \infty} (1 + n^{-1})^n \approx 2.718.
\] Of course, if \( x_n = 0 \), then the numerator of Eqn 10 would simply be 1 as any base taken to the power of 0 is 1. Thus Eqn 10 takes two slightly different forms for each type of response. The denominator of Eqn 10 is the normalising factor of these two forms which ensures that the probabilities for each type of response sum to 1 (Andrich, 1988a). The normal distribution function (Eqn 3) is not of a closed form; yet the logistic closely approximates the normal. Thus as a theory of paired comparison judgements, the Rasch model (Eqn 10) is equivalent to Thurstone’s (1928) law of comparative judgment (Eqn 2), except with the logistic function replacing the normal (Andrich, 1978).

The ‘additivity-in-the-parameter’ property of the simple Rasch model derives from the use of the person total score to calculate the person parameters. This is done by summing across \( k \) items for each person \( v \) such that 
\[
r_v = \sum_{i=1}^{k} x_{vi}.
\] Each person with the same total score gets the same parameter estimate, irrespective of the pattern of their answers. For example, a test designed to assess numerical ability is administered to a group of school children. Those children who answer \( y \) number of hard items correctly and \( z \) easy ones incorrectly and those who answer \( y \) number of easy items correctly and \( z \) hard ones incorrectly on a test receive exactly the same person estimate. This is justified by arguing that if those children who answered the difficult ones correctly but not the easy ones are not as able as their responses to the difficult items would suggest. The Rasch model also uses another statistic to calculate the item parameters, the total item score, which is summed across all \( N \) individuals such that 
\[
s_i = \sum_{n=1}^{N} x_{ni}.
\] Notice that this is similar to classical test theory but different in that the sufficient statistics for both the person and item parameters are separated from the test data. In classical test theory such statistics are subsumed under the one total observed score \( X_i \) made to test \( i \) by person \( v \).

These sufficient statistics are used by item response theorists in their various algorithms for the estimation of the pertinent parameters. There are three kinds of estimation algorithms that are typically used to estimate the parameters of Rasch models. All are based on maximum likelihood (LM) principles in which the equations are solved
iteratively using the Newton – Raphson\textsuperscript{24} method (Andrich, 1988a). These are conditional (CON), joint maximum likelihood (JML) and conditional pairwise (PCON) estimation (Andrich, 1988a). Each method has its strengths and weaknesses. The CON method of estimation is the best method theoretically but is not very efficient computationally. The JML method is computationally efficient but requires the estimates to be corrected (Andrich, 1988a). Andrich and his associates (Andrich, Lyne, Sheridan & Luo, 2001) and their computer program Rasch Unidimensional Measurement Models (RUMM) uses PCON estimation. In this algorithm, estimation is conducted on the basis of comparing the responses made to two items irrespective of other items and independently of the person parameters (Zwinderman, 1995). This is in keeping with the concept of specific objectivity (Rasch, 1977) but this estimation procedure can best accommodate missing data (Andrich, 1988a). In each of these estimation procedures the total item and person scores are used to restrict the possible values of the item and person estimates, respectively.

This separation of the item and person parameters is not just done for the practical purpose of model estimation. It is vital to the conceptual strength of the Rasch model as a quantitative theory of psychology. In particular, this separation enables the model to have the property Rasch (1977) termed ‘specific objectivity’. This simplest exposition of this is given in Andrich (1988a, pp. 25 - 29) and it is from this that the following is taken.

If a person \( v \) undertakes the completion of two different dichotomously scored items, \( i \) and \( j \), on a test \( k \), then the concept of statistical independence (as distinct from independence in axiomatic conjoint measurement) states that \( v \)'s performance on \( i \) is not dependent on \( v \)'s performance on \( j \) and vice versa. That is, if:

\[
\Pr[x_{vi} = 1] = \frac{B_i/D_i}{1 + B_i/D_i} \quad \text{and} \quad \Pr[x_{vj} = 1] = \frac{B_j/D_j}{1 + B_j/D_j}
\]

then the probability that \( v \) will make a response of ‘1’ to both items is simply the product of the probabilities that \( v \) will make a response of ‘1’ to each item, such that:

\[
\Pr[x_{vi} = 1, x_{vj} = 1] = \Pr[x_{vi} = 1] \Pr[x_{vj} = 1]
\]

which gives:

\[
\Pr[x_{vi} = 1, x_{vj} = 1] = \frac{(B_i/D_i)(B_j/D_j)}{(1 + B_i/D_i)(1 + B_j/D_j)}
\]

\textsuperscript{24} This method is used to find the roots of fifth or higher degree polynomial equations. The iterative formula is \( x_{n+1} = x_n - f(x_n)/f'(x_n) \) where \( f(x_n) \) is the relevant polynomial function, \( f'(x_n) \) is the first order derivative of that function and \( x_n \) is the initial estimate (Edwards & Penney, 1982).
Responses of either 0 to both items or 1 to both items are of little value to the Rasch model as the parameters will extend to negative and positive infinity, respectively (Hutchison, 1991). That is, these responses do not contain sufficient information to estimate the parameters of the Rasch model in any meaningful way. It is thought that such responses indicate the lower and upper limits of the test’s capacity to measure the latent trait rather that the individual possesses either infinitely lesser or infinitely greater ability. The response patterns in which only one item is scored correctly given that either item can be scored correctly does contain the necessary information to estimate the parameters. This can be easily demonstrated using the odds ratio:

\[
\frac{\Pr[(1,0)]}{\Pr[(0,1)]} = \left( \frac{B_i}{D_i} \right) \left( \frac{1+B_j/D_j}{1+B_i/D_i} \right) = \frac{1/D_i}{1/D_j} = \frac{D_j}{D_i}
\]

As can be seen, the person parameter has dropped out of the equation, meaning that when only either one, but not both, of the items i and j are either endorsed or correctly responded to, the unit of comparison is the odds of endorsing or correctly responding to one item rather than the other (Andrich, 1988a).

A concrete example will illustrate the above. Suppose i and j were dichotomous items designed to assess performance in English. Suppose that they were administered to a group of 517 Year 7 school students. It was found that 150 responded incorrectly to both items and 50 responded correctly. This left 317 students who responded to either but not both items correctly. It was found that of these students, 256 responded to item i correctly and j incorrectly whilst 61 responded to j correctly and i incorrectly. Then the estimate is \( \hat{D}_j / \hat{D}_i = 256/61 = 4.20 \). This is interpreted as meaning that j was a little over four times as difficult as i. In other words, if any other student not in the above sample attempted both items, and only got one of the items correct, the odds that it was i over j are about 4.20:1 (Andrich, 1988a). Of course, the natural log can be taken of these odds such that \( \ln(\hat{D}_j / \hat{D}_i) = \ln(256/61) = 1.43 \), meaning that \( \hat{D}_j - \hat{D}_i = 1.43 \). Substituting this natural logit into Eqn 10 yields the theoretical probability that i would be answered correctly over j, which in this case is \( .81 \). Notice that these calculations did not involve the estimation of the English abilities of the students which means that the difficulty of the items is independent of the ability of the persons.

The term specific objectivity was coined by Rasch (1977). In general terms, objectivity means that the comparison of any pair of parameters is independent of any other parameters or comparisons. Specific means that such a comparison is made relative to a
specific frame of reference (Andrich, 1988a). The concept of specific objectivity can also be derived from the modern form of the Rasch model. This is rather lengthy, however, it demonstrates quite clearly the concept.

Attention is again focussed on the instances where one item is answered correctly (or endorsed) whilst the other is answered incorrectly (or disendorsed). This requires the calculation of the joint outcome probabilities of the instances where item $i$ is correct and $j$ incorrect and where item $j$ is correct and $i$ incorrect, such that:

$$\Pr[x_i = 1 \text{ and } x_j = 0] = \frac{1}{1 + e^{\beta_i - \delta_i}} \frac{1}{1 + e^{\beta_j - \delta_j}} e^{\beta_j - \delta_j} 11$$

and

$$\Pr[x_j = 1 \text{ and } x_i = 0] = \frac{1}{1 + e^{\beta_j - \delta_j}} \frac{1}{1 + e^{\beta_i - \delta_i}} e^{\beta_i - \delta_i} 12$$

As noted by Rasch (1977), the Poisson distribution has the desirable property in that the sum of two Poisson distributed variables is also Poisson distributed with a parameter that is the sum of the preceding parameters. This convenient property is also shared by the normal (Eqn 3) and logistic (Eqn 10) functions. Thus the above outcome probabilities sum to give the total conditional probability that one item is correct and the other is wrong:

$$\Pr[T] = \frac{1}{(1 + e^{\beta_j - \delta_j})(1 + e^{\beta_i - \delta_i})} (e^{\beta_i - \delta_i} + e^{\beta_j - \delta_j}) 13$$

The probability of item $i$ being correct whilst item $j$ is wrong can be given by the ratio of the probability of joint outcome where $i$ is correct against the total conditional probability of one item being correct whilst the other item is wrong, such that:

$$\Pr[x_i = 1, x_j = 0 \mid x_i = 1, x_j = 0 \text{ OR } x_i = 0, x_j = 1] = \frac{\frac{1}{1 + e^{\beta_j - \delta_j}} \frac{1}{1 + e^{\beta_i - \delta_i}} e^{\beta_j - \delta_j}}{\frac{1}{1 + e^{\beta_j - \delta_j}} \frac{1}{1 + e^{\beta_i - \delta_i}} (e^{\beta_i - \delta_i} + e^{\beta_j - \delta_j})} 14$$

Cancelling the common terms in the numerator and denominator gives:

$$= \frac{e^{\beta_i - \delta_i}}{e^{\beta_i - \delta_i} + e^{\beta_j - \delta_j}} 15$$

Factorising the denominator and numerator gives:

$$= \frac{e^{\beta_i - \delta_i}}{e^{\beta_j - \delta_j}} 16$$
Finally, cancelling the common terms again yields:

$$\text{Pr}[x_{vi} = 1, x_{vj} = 0 \mid s_i = 1] = \frac{e^{-\delta_i}}{e^{-\delta_i} + e^{-\delta_j}}$$

Hence that the probability that $i$ is answered correctly and $j$ incorrectly given the conditional probability that one item is correct and the other incorrect can be estimated from the ratio of item $i$'s location against the sum of the locations of $i$ and $j$. The ability of the person who completes both items is not pertinent, thus person abilities and item difficulties are independent. Thus the difficulty of the items is invariant under administration to populations of subjects of differing abilities. As the total item score

$$s_i = \sum_{i=1}^{N} x_{vi}$$

is a sufficient statistic for the estimation of the items parameters, and as the total item score is 1 for persons answering one item correctly and not the other, the above can be more elegantly written as:

$$\text{Pr}[x_{vi} = 1, x_{vj} = 0 \mid s_i = 1] = \frac{e^{-\delta_i}}{e^{-\delta_i} + e^{-\delta_j}}$$

Conversely, as $r_v = \sum_{j=1}^{k} x_{vj}$ is the sufficient statistic for ability parameter, the ability parameters of any two individuals $v$ and $\nu$ can be estimated independently of any item $i$, such that:

$$\text{Pr}[x_{vi} = 1, x_{\nu i} = 0 \mid r_v = 1] = \frac{e^{-\beta_v}}{e^{-\beta_v} + e^{-\beta_\nu}}$$

Thus the comparison of the abilities of two individuals does not involve the populations from which the individuals were drawn. Rasch (1980, pp. 3 - 4) stated:

Each model implies two types of parameters, a “difficulty” for each test (or item) and an “ability” for each person. The “difficulties” of the tests of course have to be estimated from the body of data available, i.e. the results in two or more tests (or items) for each person of a certain collection. This collection, however, is not taken to be a sample from any “population”. On the contrary, the estimation procedure may be so conducted that the personal parameters – the “abilities” – and their possible distributions are eliminated. Similarly the “ability” of each person has to be estimated from the results of the tests applied to him, but the estimation procedure yields a result that is independent of which particular set of tests (or items) has been employed.

This separation of item and person parameters is crucial. In essence, it states that person ability and item difficulty are separate, non-interactive and unidimensional psychological attributes. The concept of specific objectivity is very much like the
independence or single cancellation axiom of additive conjoint measurement (Krantz, et al, 1971) in which the weak ordering upon one attribute is independent of the weak ordering upon the other. As such, the collapse of specific objectivity in the Rasch model is akin to the falsification of the independence axiom in conjoint measurement; in that the attributes (parameters) interact and thus confound the test of additivity:

Firstly, the failing of specific objectivity means that the conclusion about, say, any set of person parameters will depend on which other persons are also being compared. As a parody we might think of the comparison of the volumes of a glass and a bottle as being influenced by the heights of some of the books on a shelf. Secondly, the conclusions about the persons would depend on just which items were chosen for the comparison, a situation to which a parallel would be that the measurement [of] the relative height of two persons would depend on whether the measuring stick was calibrated in inches or in centimetres (Rasch, 1977, p67).

Rasch, however, was not the first to note this property. Luce (1959) in his choice model set down what is now known in random utility theory as the Independence from Irrelevant Alternatives (IIA) axiom. This axiom states that the choice made between 2 objects in any choice set is independent of the presence of any other choice alternatives in that set. For any unordered choice set \( J \) which contains finite \( j \) elements or choice alternatives, the Luce model argues that the probability that the alternative \( i \) is chosen over alternative \( j \) is given by:

\[
Pr[i | g, h, i, j, \ldots k \in J] = \frac{e^{V_i}}{\sum_{j} e^{V_j}}
\]

where \( V_i \) is the utility of the \( i \)th alternative and the denominator is the summation of all of the utilities of the all other choice alternatives in the set. In random utility theory these utilities are estimated empirically as the standardised beta weights on the right hand side of a multinomial logistic regression equation. The IIA property can be derived directly from the Luce model. For any two alternatives \( i \) and \( j \) in the set \( J \) of choice alternatives, the ratio of the logit probabilities is given thus:

\[
\frac{Pr[i]}{Pr[k]} = \frac{e^{V_i}/\sum_{j} e^{V_j}}{e^{V_j}/\sum_{j} e^{V_j}}
\]

Cancelling common terms yields:

\[
\frac{Pr[i]}{Pr[k]} = \frac{e^{V_i}}{e^{V_j}} = e^{V_i - V_j}
\]
thus proving the IIA property (Train, 2002). The connection between the IIA property and specific objectivity (Rasch, 1977) can be formalised by recognising that Eqn. 18 reduces to a special form of the Luce model, such that:

\[
\Pr[x_{v1} = 1, x_{v2} = 0 | s_1 = 1] = \frac{e^{-\delta_1}}{(e^{-\delta_1} + e^{-\delta_2})} = \frac{1}{\sum_{i=1}^{n} e^{-\delta_i}}
\]

Similarly to the Rasch model, the Luce choice model is a derivation of Thurstone’s law of comparative judgement. Yellot (1977) proved axiomatically that the Luce choice model is Thurstone’s theory with the exception that in the former errors are taken to have the double exponential or Weibull cumulative distribution function \( y = \exp(-\exp(-x)) \), over the normal. The property of this distribution which makes it attractive to random utility theorists is that choice alternatives with high utilities have probabilities of being selected rapidly approaching one whilst alternatives with low utilities have selection probabilities rapidly approaching zero. Michell (1990) claimed that the Luce choice model could be tested using axiomatic conjoint measurement in the same way that he demonstrated Thurstone’s theory could. This is important as Luce (1977) has claimed that given the IIA axiom his choice model is a probabilistic version of his work into axiomatic utility theory.

This conclusion of Luce’s raises the following question. If Luce’s IIA property and Rasch’s (1977) concept of specific objectivity are synonymous, and if Luce’s choice model is indeed a probabilistic version of a determinist theory of utility measurement, then given the independent nature of item difficulty and person ability, could the Rasch model be a probabilistic version of binomial, additive axiomatic conjoint measurement (Krantz, et al, 1971)? The following section addresses this question.

6.3 The Rasch (1960) one – parameter logistic model as probabilistic conjoint measurement

The preceding discussion concerning the concept of specific objectivity has been intuitive and informal. Rasch (1977) proposed a formal and general model of this important concept.

In any instance of measurement either in the natural or social sciences, Rasch argued of the existence two theoretical sets or collections of elements. One set \( A \) contained the elements pertinent to what he termed agents. The other set, \( O \), contained elements pertinent to what he termed objects. Rasch stipulated that the sets were non-empty but could contain either an infinite or finite number of elements.
Rasch argued that every \( o_i \in O \) and every \( a_v \in A \) could enter into a specific relation which he termed a *contact*, \( c \). Such contacts formed the non-empty set \( C \). All \( c_{iv} \in C \) are the pairs \((o_i, a_v)\). Every such contact had an *outcome*, \( r \), and the non-empty set of all outcomes was \( R \). Rasch argued that \( R \) could contain any type of elements, like those of a Bernoulli outcome variable or the all of the positive real numbers.

The presence of the specified sets \( O, A \) and \( R \) gave what Rasch called the *bifactorial frame of reference* (presumably the empirical circumstances of measurement) from which the *concept of comparison* (presumably the act of measurement) could be defined. In any such frame of reference where each \( c_{iv} \in C \) determines each outcome \( r \in R \) uniquely, then there exists a *single valued correspondence function* isomorphically mapping the elements of \( C \) into \( R \), such that \( r_{iv} = \phi(o_i, a_v) \). In this instance, the frame of reference is *determinate*.

Within a determinate frame of reference, Rasch argued that a *comparison* between two objects \( o_i \) and \( o_k \) is solely defined on the basis or their reactions with \( a_v \) such that \( r_{iv} = \phi(o_i, a_v) \) and \( r_{kv} = \phi(o_k, a_v) \). As such, a *comparing function* \( \psi \) operates on \( r_i \) and \( r_k \) such that \( \psi(r_i, r_k) = \psi(\phi(o_i, a_v), \phi(o_k, a_v)) = \gamma(o_i, o_k \mid a_v) \). Therefore, the reactions are consequent only of the objects and not of the agent within the specified frame of reference. Hence the reactions are *objective* and *specified*; and so hence the term ‘*specific objectivity’*.

Rasch argued that within specifically objective frames of reference, the elements \( o_i, a_v \) and \( r_i \) can be assigned real-valued scalar parameters \( \sigma_i, \alpha_v \) and \( \xi_{iv} \), respectively. If the objects and agents within a bifactorial frame of reference are characterised by their respective scalar parameters and by a scalar *reaction function* \( \rho \) possessing ‘convenient’ mathematical properties such that \( \xi_{iv} = \rho(\sigma_i, \alpha_v) \); then there exists the strictly monotonic functions \( \xi'_{iv} = \eta(\xi_{iv}) \), \( \sigma'_i = \iota(\sigma_i) \) and \( \alpha'_v = \kappa(\alpha_v) \). These monotone transformations of the scalar parameters enter into the following non-interactive, additive axiomatic conjoint-type relation:

\[
\xi'_{iv} = \sigma'_i + \alpha'_v
\]

Thus the above argues that the monotonically transformed scalar response parameter is produced by a non-interactive additive function upon the monotonically transformed scalar object and agent parameters. This is characteristic of axiomatic conjoint
measurement (Krantz, et al, 1971, Michell, 1990). Moreover, Rasch (1977) argued that additivity in the scalar monotone transformations resides in their differences such that:

\[ \xi'_w - \xi'_m = \alpha'_w - \alpha'_m \text{ and } \xi'_v - \xi'_w = \alpha'_w - \alpha'_v \]

If the object parameter represents a magnitude of the attribute of person ability, and if the agent parameter represents a magnitude of the attribute of item difficulty, then the Rasch model proposes that each attribute yields real-valued measures unique up to positive linear transformations (Michell, 1986). That is, the attributes of concern to the Rasch model are held to be interval scalable. Rasch (1977) argues that this exists only when Eqn 6 is true as with only this equation does the simple logistic model between person ability and item difficulty hold. If the conditional probabilities mentioned earlier cannot be calculated then this model does not hold. If Eqn 6 does not hold then the estimation of either attribute independently of the other cannot occur. This follows as a result of the simple logistic model. If Eqn 6 does hold, then the scale values are genuinely population free estimates. Invariant estimates of the scale values of the person and item attributes is also the goal of axiomatic conjoint measurement theory.

A long term proponent of the Rasch model as probabilistic axiomatic conjoint measurement is Benjamin Wright (Masters & Wright, 1984; Perline, Wright & Wainer, 1979). Perline, et al, (1979) argued that the concept of specific objectivity renders the Rasch model: "...a practical example of how conjoint measurement can be applied to empirical data" (p.238). They wrongfully dismissed, however, the algebraic cancellation conditions of axiomatic conjoint measurement as "rule of thumb guidelines" (p.238) and purported that the standard statistical tests of fit used with the Rasch model were indeed superior. The Thomsen condition axiom (Krantz et al, 1979) is the necessary and sufficient condition for forcing an additive strict simple order (one that is transitive, antisymmetric and strong connected) upon the component sets of the conjoint matrix and their Cartesian product. The Thomsen condition is a logical derivation from the axiomatic conjoint model; similarly to how specific objectivity is in the Rasch model. Neither are arbitrary or potentially trivial "rules of thumb", hence the dismissal of the cancellation conditions by Perline et al should be noted but dismissed itself.

Once having dismissed them, Perline et al later attempted to explain the independence and Thomsen condition axioms (Krantz, et al, 1971). Reiterating the arguments of Krantz & Tversky (1971), Perline et al stated that with the stronger form of the Thomsen condition, the double cancellation condition, there exists the class of algebraic relations
which result in a 'no - test' of double cancellation. This is incorrect. Michell (1988) demonstrated that the 'no-test' relations are indeed acceptances and Michell (1990) provided a convenient table in which acceptances and violations of double cancellation are easily recognised. Perline et al (1979, pp. 242-243) then add that the Thomsen axiom is not a sufficient condition for additivity, only the higher order cancellation conditions (Scott, 1964) are:

However, both monotonicity [independence] and double cancellation are only necessary, not sufficient, conditions for additivity...Necessary and sufficient conditions are given by Scott (1964) and Tversky (1967).

This is also incorrect. Double cancellation is a sufficient condition for additivity in simple, binomial 3 x 3 conjoint matrices. The higher order cancellation conditions are indirect tests of the solvability and Archimedean axioms of conjoint measurement (Michell, 1990). For example, triple cancellation or the Reidemeister condition (Krantz, et al, 1971) can only be tested in 4 x 4 conjoint matrices. Hence in order to test these higher order conditions, the conjoint experimental 'space' (or 'frame of reference' as Rasch (1977) termed it) must be extended more levels of observation within each of the component sets of the conjoint matrix. Satisfaction of these higher order conditions necessarily entails the satisfaction of all lower order cancellation conditions (Michell, 1990).

Perline et al (1979) argues that for the Rasch model to be considered in the terms of additive conjoint measurement the following must hold:

\[ M(Pr_{iv}) = \delta_i + \beta_v \]

where the probability of person \(v\) responding to item \(i\) correctly is the sum of person \(v\)'s ability and \(i\)'s difficulty; and \(M\) is a monotone transformation acting upon the probabilities. If \(M\) is the inverse natural logistic function, then the above is the one-parameter Rasch model.

Perline et al then subjected this model to three types of analysis. The data they used came from 2500 released prisoners who have responded to 9 dichotomous items which assessed some background demographic variables, such as completed high school grade, prior incarceration and drug use history. Perline et al then formed a matrix using the items as columns and the total scores as the rows. Each cell corresponded to the observed proportion of subjects endorsing that item.

Firstly, they subjected the data to a computer program 'MONANOVA' which estimated a value for \(M\) so as to fit a usual ANOVA factorial design to the data. Additivity in the
person and item parameters would be found in the discovery of significant main effects. This type of 'conjoint measurement' is in fact the theory of 'functional measurement' proposed by Norman Anderson (1970, 1976, 1977). Anderson argued that significant main effects indicated additivity in the functional measurement ANOVA model, whilst a significant interaction term suggested a multiplicative composition rule over an additive one. Functional measurement is in fact an operational, non-axiomatic version of conjoint measurement. It is a purely statistical (and therefore not algebraic) theory and thus is not axiomatic conjoint measurement.

Perline et al found a poor fit of this model to the data, however, it did enable them to estimate item and person parameters. Secondly, Perline et al estimated the item and person parameters using the Rasch model and found a product moment correlation coefficients between the ability and item estimates of the two models of .997 and .985, respectively. Thirdly, they subjected the observed proportions to tests of double cancellation. Perline et al constructed an index of the departure of the data from additivity by calculating the ratio of the number of matrices violating double cancellation to those satisfying. This ratio would be zero if all matrices were satisfied. They found such ratios were high and concluded the data did not support the axiomatic conjoint model. They had, however, mistakenly assumed the 'no -- test' condition for tests of double cancellation, thus the ratios presented in their Table 4 were artificially high. If these ratios are recalculated to include the instances of no tests as acceptances, then the ratios are much lower. For example, Perline et al (1979, p.249) stated:

Using Direction 2 only, then, gives a ratio of total violations to total testable submatrices of 690/2916 = .24. No statistical significance value can be assigned to this value. However, as a baseline comparison, Levelt, Riemersma and Bunt (1972) analysed some empirical data in the same way and found ratios in the range of .002 to .026. Using this baseline, the parole data fall well short of a good fit.

If this particular ratio is recalculated so as to include the 'no-tests', it becomes 690/4014 = .1719, which is still much higher than their established baseline but much lower than their ratio. Recalculating their Direction 1 data yields 3/4701 = .00064, well within the baseline. If the overall data is recalculated, the ratio gives 693/8715 = .0795, which is getting close to within their baseline range. Thus the 'fit' of their data to the conjoint model, whilst not good, was certainly better than Perline et al concluded.

Perline et al then conducted the same analyses on some intelligence test data that Rasch (1960) himself had collected from Danish military recruits. They found a very good fit of
the 'MONANOVA' and Rasch models to the data with high correlations between the estimated parameters. They once again conducted tests of double cancellation upon the observed proportions obtained by Rasch. Using the data in their Table 6, if the Direction 2 ratio is recalculated to include the 'no-test' instances, then the ratio takes the value of 625/9385 = .0666. Their Direction 1 took the value of zero with no recalculation as neither 'violating' nor 'no-test' patterns were observed. The total ratio is then recalculated as 625/19395 = .0322. This ratio was almost within their established baseline. Thus while concluding that the Rasch data reflected 'considerable improvement in additivity compared to the previous example' (p. 250), the results were again much better than Perline et al thought they were.

From the strict perspective of mathematical psychology, Perline et al misinterpreted their findings. The fact that a significant proportion of the cancellation tests failed means that the hypothesis of underlying quantitative attributes combining additively must be rejected. This means that the concept of 'good fit' statistically (in this case via the MONANOVA technique) is insensitive to violations of additivity. Hence it would have been better for Perline et al (1979) to test the axioms directly than by calculating overall goodness of fit.

An interesting critique can be made of the Perline et al (1979) study. Although initially, and incorrectly, dismissing the Thomsen condition axiom (Krantz et al, 1971) as a sufficient condition for additivity, Perline et al (1979) actually use double cancellation to establish additivity on the proportional frequencies of correct response observed by Rasch. This is a rather interesting contradiction. In their assessment of Rasch's data, Perline et al had created a 13 x 7 matrix with the observed proportional frequencies as the cell entries. Such a matrix, if used in an axiomatic conjoint measurement model, would have enabled the test of at least triple and quadruple cancellation. After arguing that: "Necessary and sufficient conditions for additivity are given by Scott (1964) and Tversky (1967)" (p.243), they did not make use of the higher order cancellation conditions. Yet these higher order tests would provided much stronger evidence in support of Perline et al's very arguments. This is an interesting pattern of contradiction which perhaps suggests some confusion about axiomatic measurement theory. The dearth of studies succeeding this laudable attempt to connect Rasch and axiomatic measurement theory suggests that the thesis of the Rasch model being a probabilistic realisation of axiomatic binomial conjoint measurement has not yet been fully tested.

Chapter 5 showed how a deterministic theory of preferential choice behaviour (viz., Coombs's (1964) theory of unidimensional unfolding) could be applied in the measurement of a psychological attribute. Moreover, Chapter 5 displayed how axiomatic conjoint measurement (Luce & Tukey, 1964) could be used with Coombs's theory not only as a test of the attribute for additivity, but as a test of Coombs's theory itself.

Both its determinism and the complex task of establishing scaling solutions renders Coombs' theory as too difficult a method of psychological measurement according to IRT (Andrich, 1997). Coombs's (1964) theory is indeed intolerant of error; as technically any \( I \) scales which do not fall on the dominant path falsify the theory (Michell, 1990). Such \( I \) scales were found in the data as stated in Chapter 5. A deterministic interpretation, however, would argue that because these 'off dominant path' \( I \) scales constitute less than 5% of the total judgment data, this level of 'error' is tolerable and can be explained as the product of extraneous factors. To IRT this is an unacceptable interpretation. It argues that error, however small, should be accounted for in any quantitative model of psychology rather than dismissed. Hence it argues that if any tenable theory of unidimensional unfolding is to be developed it must incorporate erroneous \( I \) scale data, whether it be in the form of intransitive preference judgements or transitive judgments located off the dominant \( I \) scale path.

It is important to understand here, however, that the IRT and Coombs (1964) approaches represent different philosophical attitudes towards error. This was discussed earlier in the introduction to this chapter. It must be remembered that neither perspective, on its own terms, is incorrect (Luce, 1997b).

To the end of developing a probabilistic theory of unfolding, IRT models of unidimensional unfolding have recently been proposed by Andrich (1988b, 1989, 1995, 1996, 1997; Andrich & Luo, 1993; Luo, 1998, 2001; Luo, Andrich & Styles, 1998). The first such model devised by Andrich (1988b) was called the hyperbolic cosine model (HCM) of unidimensional unfolding. This particular function was the first one found to be a tenable probabilistic version of the concept of the single peaked preference function (Coombs & Avrunin, 1977). One aim of the IRT approach is to satisfy Rasch's (1977) concept of specific objectivity, in that the item and person parameters can be estimated independently. Another aim has been the empirical investigation of the concept of
‘latitude of acceptance’ (Sherif & Hovland, 1961) found in research on attitudes. Andrich & Luo (1993) and Luo (1998, 2001) have formally incorporated the concept of latitude of acceptance into their models of unfolding with the estimation of a parameter they designate ‘$\rho$’.

Andrich’s (1988b) HCM of unidimensional unfolding for paired comparison data is ingenious in its simplicity and parsimony. Moreover, it was the starting point for the empirical and theoretical work which cleverly unified the hitherto disparate ideas of Thurstone’s (1928), Coombs’ (1946) and Likert’s (1932) (Andrich, 1996). As stated earlier, Andrich (1978) investigated the application of IRT to both graded response items used in human performance assessment and Likert’s (1932) theory of summated rating scales. The model takes the form (Andrich, DeJong & Sheridan, 1997, p.60):

$$
\Pr[x_{vi} = x] = \frac{1}{\gamma_{vi}} \exp \left[ -\sum_{s=1}^{m} \tau_{vs} + x(\beta_v - \delta_i) \right]
$$

where $x_{vi}$ is a random variable taking positive integer values such that $x_{vi} \in \{0,1,2,...,m\}$. These positive integers can represent either of two things depending upon the type of item. Firstly, with items designed to assess some aspect of human performance, these values can represent the levels at which responses to such items are graded. For example, a mathematics question may be graded ‘0’ for an incorrect or absent response with no working, ‘1’ an incorrect answer with working, ‘2’ a correct answer without working and ‘3’ for a correct answer with working. Secondly, if the items are statements which use Likert’s (1932) theory of summated ratings to elicit responses, the integers ‘1’, ‘2’, ‘3’, ‘4’ and ‘5’ may represent the semantic categories of ‘Never’, ‘Rarely’, ‘Sometimes’, ‘Often’ and ‘Always’, respectively. The normalising factor is

$$
\gamma_{vi} = \sum_{x=0}^{m} \exp \left[ -\sum_{s=1}^{m} \tau_{vs} + x(\beta_v - \delta_i) \right]
$$

which ensures that the probabilities of responses to any category sum to zero. Importantly, it contains the probabilities of exceeding all thresholds for all categories, so that the probability of person $v$ scoring in category $s$ depends upon the locations of all thresholds (Andrich, et al, 1997). This is done so that responses to a graded item or rating scale are constrained to a Guttman-like pattern (Andrich, et al, for a derivation of the model see Andrich, 1978). The threshold location of category $s$ for item $i$ is represented by the parameter $\tau_{si}$; $\beta_v$ is the person parameter, $\delta_i$ is the item parameter.
Figure 6.1: A generic graded response item with three categories.

Figure 6.1 displays the cumulative response curves of a graded response item with three categories ‘0’, ‘1’ and ‘2’. In this case, the item fit is discerned from two things. Firstly, the value and statistical significance of the chi-square statistic and secondly, the order of the two thresholds. The locations of the thresholds are discerned by the intersection of the curves for the categories ‘0’ and ‘2’ (the two ‘outer’ curves) with the curve for the category ‘1’ (the ‘inner’ curve). Each threshold denotes the point upon the latent trait at which the probability of scoring in category $x$ equals the probability of scoring in category $y$. As the person location parameter values increase so does the probability of scoring higher. This particular item must function well as there are definite regions (areas under the curves) where each category has a greater probability of being scored than the other categories. This also means that the thresholds are in the order in which we expect them to be for a graded item with three categories.

Andrich (1996) correctly reasoned that the most important quantitative feature of Coombs’s (1964) theory of unidimensional unfolding was the single peaked preference function. Andrich intuitively observed that a convenient, probabilistic single peaked function could be realised from his work on the cumulative Rasch model for ordered response categories (Andrich, 1978).

Consider the curves for the categories of ‘0’, ‘1’ and ‘2’ displayed in Fig. 6.1. Andrich reasoned laterally that in an unfolding context, such curves could represent three kinds of latent, cumulative responses to one particular statement. The curve representing the category ‘0’ could represent in an unfolding context the latent, cumulative response of ‘Disagree Below’. That is, the person disagreed with the statement (or item) because the
statement is located on the relevant dimension below the person’s ideal point. Employing a converse argument, the curve representing the category ‘2’ could represent in an unfolding context the latent, cumulative response of ‘Disagree Above’. That is, the person disagrees with the statement because the statement is located above the person’s ideal point. The curve of the category ‘1’ could represent in an unfolding context a latent, cumulative response of ‘Agree Close’.

As the curves present the probabilities of a response made to that category in the cumulative model, Andrich reasoned that the ‘Disagree Below’ and ‘Disagree Above’ probabilities could be summed or folded to give the probability of the manifest disagree response. Once this is calculated, of course, the probability of the manifest agree response to the statement could be easily calculated. Andrich argued:

The probability of a Disagree response has a single trough. This arises because there are two reasons why a person may disagree to a statement — one because the person perceives him or herself to be below the statement at the moment of responding, the other because the person perceives him or herself to be above the statement. Thus there are two latent responses which produce the single manifest Disagree response in the unfolding direct-response design (1996, p.350, original emphasis).

Andrich argued that two different types of responses to a statement are being made in an unfolding situation — a manifest and a latent. The manifest response is the observed response of the person agreeing or disagreeing with the statement. The latent response is the cumulative unobserved processes of the latent responses of ‘Disagree Below’, ‘Agree Close’ and ‘Disagree Above’. Andrich formalised these response types in the following manner.

Let $X_{ni}$, $x_{ni} \in \{0,1\}$ be the random Bernoulli outcome variable representing the manifest ‘Disagree’ and ‘Agree’ responses made to any particular statement. This variable is of the same kind as that employed in cumulative models such as the Rasch (1960). It arises in the unfolding situation when study participants have been required to complete paired comparison tasks (such as those described in Chapter 5). $X_{ni}$ can also be generalised such that $x_{ni} \in \{0,1,2,\ldots,m\}$ where there are $m + 1$ ordered categories. This generalisation is useful for when the data collected is of the rating or ‘Likert’ scale form. Let $Y_{ni}$, $y_{ni} \in \{0,1,2\}$ be a random variable representing the latent responses of ‘Disagree Below’, ‘Agree Close’ and ‘Disagree Above’, respectively. $Y_{ni}$ can also be generalised to $y_{ni} \in \{0,1,2,\ldots,2m\}$.

---

25 For a complete derivation of the hyperbolic cosine model for paired comparison data see Andrich (1997).
Establishing these, Andrich argues that probability of the manifest ‘Disagree’ response \( X_{ni} = 0 \) is equal to the sum of the probabilities of the latent ‘Disagree Below’ and ‘Disagree Above’ responses such that:

\[
\Pr\{X_{ni} = 0\} = \Pr\{Y_{ni} = 0\} + \Pr\{Y_{ni} = 2\} \quad 28
\]

It is this equation upon which the ‘unfolding’ term applied. Andrich argues here that the two latent disagree responses are ‘folded’ together in order for them to comply with the observed, manifest disagree response. Likewise in reverse direction, the manifest, single trough disagree response can be decomposed or ‘unfolded’ into the constituent latent disagree responses (Andrich, 1996).

Applying the cumulative model for ordered response categories to the latent response variable \( Y_{ni} \) gives:

\[
\Pr\{Y_{ni} = y | \beta_n, \delta_i, \kappa_{yi}\} = \frac{\exp\{\kappa_{yi} + y(\beta_n - \delta_i)\}}{\sum_{k=0}^{2m} \exp\{\kappa_{ki} + k(\beta_n - \delta_i)\}} \quad 29
\]

where \( \beta_n \) and \( \delta_i \) are the respective locations of the persons and the items upon the latent response variable \( Y_{ni} \) and \( \kappa_{yi} = -\sum_{k=1}^{r} \tau_k \) or the sum of all \( k \) thresholds for \( y \) categories for each statement \( i \) (Andrich, 1996). When \( y = 0 \) then \( \kappa_{0i} \) and \( \kappa_{2mi} \) are set to zero without loss of generality (Andrich, 1978). The above can be substituted into the above equation for the manifest ‘Disagree’ response and common terms cancelled such that:

\[
\frac{2 \cosh(\beta_n - \delta_i)}{\exp \kappa_{ii} + 2 \cosh(\beta_n - \delta_i)} \quad 30
\]

\[
\frac{\exp \kappa_{ii}}{\exp \kappa_{ii} + 2 \cosh(\beta_n - \delta_i)} \quad 31
\]

where \( \cosh(x) = \frac{\exp(-x) + \exp(+x)}{2} \). Thus results the hyperbolic cosine model for statements upon which paired comparison tasks have been undertaken.

The hyperbolic cosine model for rating scale data is somewhat complex and not easily stated. Given the generalised definitions of the random variables \( X_{ni} \) and \( Y_{ni} \) mentioned earlier, \( X_{ni} \) takes the form of a finite sequence of integers \( m \) bounded by the length of the rating scale employed; and \( Y_{ni} = 2m + 1 \) (Andrich, 1996). The unfolding equation for the rating scale model is:

\[
\Pr\{X_{ni} = x | x < m\} = \Pr\{Y_{ni} = x\} + \Pr\{Y_{ni} = 2m - x\} \quad 32
\]
then the hyperbolic cosine model for rating scale data is:

\[
Pr\{X_{ni} = x | x, m\} = \frac{(\exp \kappa_{xi})^2 \cosh[(m - x)(\beta_n - \delta_i)]}{\exp \kappa_{xi} + (\exp \kappa_{xi})^2 \cosh[(m - x)(\beta_n - \delta_i)]}
\]

\[
Pr\{X_{ni} = m | x, m\} = \frac{\exp \kappa_{xi}}{\exp \kappa_{xi} + (\exp \kappa_{xi})^2 \cosh[(m - x)(\beta_n - \delta_i)]}
\]

Andrich used an example to clarify the arguments presented in the above equations. With cumulative items, if the semantic categories of ‘Strongly Agree’, ‘Agree’, ‘Disagree’, ‘Strongly Disagree’ were scored on a 4-point Likert type rating scale as ‘0’, ‘1’, ‘2’ and ‘3’, respectively, it could be easily seen that higher total scores made to a set of such items indicated greater disagreement. In an unfolding situation, however, this cannot be argued. According to Andrich, the latent response process would be in accordance with the basic unfolding equation such that the categories would be ‘Strongly Disagree Below’, ‘Disagree Below’, ‘Agree Below’ ‘Strongly Agree’, ‘Agree Above’, ‘Disagree Above’, ‘Strongly Disagree Above’. Thus \( x_{ni} \in \{0,1,2,3\} \) and \( y_{ni} \in \{0,1,2,3,4,5,6\} \) (Andrich, 1996).

The hyperbolic cosine models for paired comparison and rating scale data as written in Eqns 30, 31, 33 and 34 are rather inelegant. Andrich & Luo (1993) introduced the unit parameter to the unfolding model for paired comparisons. Luo (1993, 1998, 2001) has developed the rating scale models (Equations 33 & 34) further and has introduced what he calls a latitude of acceptance parameter. As demonstrated in Chapter 5, Coombs (1964) argued that a person’s ideal point did not necessarily have to fall directly upon his or her preferred statement. If the individual’s preference function was single peaked and symmetric it would provide the region within which a statement would be the preferred one. The models displayed in Eqns. 30–34 lack this particular feature and so hence are conceptually restricted as probabilistic models of unidimensional unfolding.

For the unfolding model for paired comparisons (Equations 30 & 31), Andrich & Luo (1993) argued that the distance between the first and second thresholds could represent a unit parameter \( \theta_i \) for any statement \( i \) such that \( \tau_{ii} - \tau_{ii} / 2 = \theta_i \). Thus \( \theta_i \) represents the distance between statement \( i \)'s location and each threshold. This parameter measured on the relevant, latent dimension the intersection of the latent ‘Disagree Above’ (DA) and ‘Disagree Below’ (DB) response curves with the manifest ‘Agree’ curve (AC). Thus at the first threshold \( (\tau_{ii}) \) the DB and AC latent responses have an equal probability of
occurring and at the second \((r_{zj})\) the DA and AC responses also have an equal probability of occurring. If Fig. 6.1 is taken as depicting these latent responses, \(\theta_i\) measures the intersection of the two outer curves (DA & DB) with the middle single peaked (AC) curve. Let \(X_{ni}\), \(x_{ni} \in \{0,1\}\) be a random Bernoulli outcome variable and let \(\beta_n\) and \(\delta_i\) be the locations of the person and the item on the single, relevant dimension. Introducing \(\theta_i\), the hyperbolic cosine model for paired comparison data is reparameterised such that:

\[
\Pr[x_{ni} = 1 | \beta_n, \delta_i, \theta_i] = \frac{\exp(\theta_i)}{\exp(\theta_i) + 2 \cosh(\beta_n - \delta_i)} \quad 35
\]

\[
\Pr[x_{ni} = 0 | \beta_n, \delta_i, \theta_i] = \frac{2 \cosh(\beta_n - \delta_i)}{\exp(\theta_i) + 2 \cosh(\beta_n - \delta_i)} \quad 36
\]

where \(\theta_i\) is the statement unit which governs the height and width of the single peaked manifest 'Agree' curve (Andrich, 1995; Andrich & Luo, 1993). Equations 35 & 36 are known as the simple hyperbolic cosine models (SHCM) for paired comparisons (Andrich, 1996). The SHCM is valid iff \(\theta_i \geq \ln 2\). If the value of \(\theta_i\) does not equal nor exceed the natural logarithm of 2 (.693), Andrich & Luo (1993) argued that probability for a manifest 'Agree' response is always less than the probability of a latent 'Disagree' response regardless of the values of \(\beta_n\) and \(\delta_i\). Setting \(\theta_i = \ln 2\) means that the expected probability of a manifest agree response is equal to .5 if the model fits the data. Values higher than \(\ln 2\) can be used if mathematically convenient (Andrich & Luo, 1993).

The SHCM, however, still contains two different continuous mathematical functions, the exponential and the hyperbolic cosine. To obtain a more parsimonious model containing only the latter function, Luo (1998) argued of another parameter \(\rho_i\) such that \(\exp(\theta_i) = 2 \cosh(\rho_i)\). This equation holds because \(\cosh(0) = 1\) and \(\rho_i > 1\), therefore \(\exp \theta > 2\) (Andrich, 1996). Introducing the \(\rho_i\) 'latitude of acceptance' (Sherif & Hovland, 1961) parameter to Eqns. 35 and 36 and cancelling common terms results in:

\[
\Pr[X_{ni} = 1 | \beta_n, \delta_i, \rho_i] = \frac{\cosh(\rho_i)}{\cosh(\rho_i) + \cosh(\beta_n - \delta_i)} \quad 37
\]

\[
\Pr[X_{ni} = 0 | \beta_n, \delta_i, \rho_i] = \frac{\cosh(\beta_n - \delta_i)}{\cosh(\rho_i) + \cosh(\beta_n - \delta_i)} \quad 38
\]
The presence of $\rho_i$ in Eqns. 37 and 38 means that the manifest ‘Disagree’ response does not have to be resolved into the two latent ‘Disagree Above’ and ‘Disagree Below’ responses (Luo, 1998). Eqns. 36 & 37 form the generalised hyperbolic cosine model (GHCM) for rating scale data (Andrich, 1996). Once establishing $\rho_i$ in the hyperbolic cosine unfolding model, Luo recognised that Eqn. 37 was a special instance of a general probabilistic theory of unidimensional unfolding. Luo (1998, 2001) proposed that the general model took the form:

$$\Pr\{X_{ni} = 1 | \beta_n, \delta_i, \rho_i\} = \frac{\psi(\rho_i)}{\psi(\rho_i) + \psi(\beta_n - \delta_i)}$$  \hspace{1cm} (39)

For $\psi$ to be an unfolding function Luo argued that it must possess the following three properties:

1. **Non-negative:** $\psi(x) \geq 0$ for any real valued $x$.
2. **Monotonic in the positive domain:** $\psi(x_1) > \psi(x_2)$ for any $x_1 > x_2 > 0$; and
3. **Symmetric about the origin:** $\psi(x) = \psi(-x)$ for any real valued $x$.

If possessing these three properties, Luo (1998, p.405) defined $\psi$ as the operational function of the general unfolding model. Luo argued that these three properties ensured that $\psi$ was indeed single peaked. Firstly, 1/ ensured that the probability of the manifest ‘Agree’ response was non-negative when $\psi(\rho_i) = 0$. Secondly, 2/ meant that as $\psi$ increases in the positive domain, then for any fixed $\rho_i$ Eqn. 38 would monotonically decrease as $|\beta_n - \delta_i|$ increased. Thirdly, 3/ ensures that Eqn. 38 is governed by $|\beta_n - \delta_i|$, meaning that $\psi$ has a maximum when $|\beta_n - \delta_i| = 0$. The presence of $\psi$ in Eqn. 38 then means that Eqn. 38 is truly single peaked.

Like the SHCM models depicted in Equations 35 & 36, the hyperbolic cosine model for polytomous responses (Equations 33 & 34) can be reparameterised into the generalised hyperbolic cosine model (GCHM, Luo, 2001) such that:

$$\Pr\{X_{ni} = k\} = \frac{\exp[k(2m-k)\theta_i \cosh((m-k)(\beta_n - \delta_i))]}{\gamma_{ni}}, \hspace{1cm} k = 0, ..., m - 1,$$  \hspace{1cm} (40)

$$\Pr\{X_{ni} = m\} = \frac{\exp[m^2 \theta_i]}{\gamma_{ni}}$$  \hspace{1cm} (41)

where $\theta_i$ is the unit parameter defined in the reparameterised Rasch model for ordered response categories (Andrich, 1982); wherein the distances between the thresholds are
constrained to be both equal and positive. Reparameterising Eqn. 40 to include the latitude of acceptance parameter $\rho_u$ results in the general formulation of polytomous unfolding models (Luo, 2001):

$$\Pr\{X_m = k \mid \beta_n, \delta_i, \rho_u\} = \frac{\left(\prod_{i=1}^{k} \psi_i(\rho_u)\right)\left(\prod_{i=k+1}^{m} \psi_i(\beta_n - \delta_i)\right)}{\lambda_{ni}}, \quad k = 0, \ldots, m$$

where $\lambda_{ni} = \sum_{k=0}^{m} \left(\prod_{i=1}^{k} \psi_i(\rho_u)\right)\left(\prod_{i=k+1}^{m} \psi_i(\beta_n - \delta_i)\right)$ is the normalising factor. See Luo (2001) for a complete proof of this model.

In addition to the hyperbolic cosine, there are a variety of functions which will render Eqns. 39 & 42 into an unfolding model. Andrich (1988b) argued of the simple squared logistic function (SSLM) where $\psi(\beta_n - \delta_i) = \exp[(\beta_n - \delta_i)^2]$ and $\psi(\rho_i) = \exp[(\rho_i)^2]$. Hoijtink (1990, 1991, 1997) argued of the square function or PARELLA function such that $\psi(\beta_n - \delta_i) = [(\beta_n - \delta_i)^2]^\gamma$ and $\psi(\rho_i) = (\rho_i^2)^\gamma$. Luo (1998) proposed that even the secant and arc tangent functions could be employed such that $\psi(\beta_n - \delta_i) = \sec[\arctan(\beta_n - \delta_i)]$ and $\psi(\rho_i) = \sec[\arctan(\rho_i)]$. These functions together with the hyperbolic cosine function constitute what I call the family of continuous, probabilistic unfolding functions.

6.5 The Empirical Test of the Subjective Control Scales via the family of Probabilistic Unfolding Functions.

6.5.1 Aims

The aim of the present study was threefold. The first aim was to test the family of probabilistic unfolding functions on the data obtained using the procedures outlined in Chapter 5. This data includes both the rating scale and paired comparison tasks. The second was to compare the obtained probabilistic solutions between the test and retest phases of data collection for both types of collected data. The third was to compare the results of the probabilistic analyses with the deterministic analysis conducted in Chapter 5.

6.5.2 Design

As per Chapter 5

6.5.3. Participants

As per Chapter 5
6.5.4 Materials
In addition to the materials employed in Chapter 5, two specialist computer programs were used to analyse the rating scale data and the paired comparison data. These were, respectively RATEfold 2002 Version 2.0.3 (Luo and Andrich, 2002) and RUMMFOLDpp Version 2.1 (Andrich & Luo, 1998). All analyses were conducted by the author on a Pentium PC.

6.5.5 Procedure
As per Chapter 5

6.6 Results

6.6.1 Item locations & latitude of acceptance parameters of the rating scale model
Tables 1 to 14 below present the summaries for each version of the Subjective Control scales under both the test and re-test conditions. Contained in each table are the location ($\delta_i$) and latitude of acceptance ($\rho_i$) parameters (measured in natural logits) of each statement together with the pertinent standard errors of the estimates.

It was found for all three of the Subjective Control scales across both test and retest phases that the hyperbolic cosine and squared logistic functions enabled the general unfolding model to best fit the ratings data. The RATEfold program was able to compute a PARELLA model for only the general version of the Subjective Control scales. It could not do so for the other versions.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.762 (.030)</td>
<td>.131 (.001)</td>
</tr>
<tr>
<td>B</td>
<td>.375 (.032)</td>
<td>.073 (.000)</td>
</tr>
<tr>
<td>C</td>
<td>-.148 (.035)</td>
<td>.051 (.000)</td>
</tr>
<tr>
<td>D</td>
<td>-.148 (.038)</td>
<td>.003 (.000)</td>
</tr>
<tr>
<td>E</td>
<td>-.304 (.037)</td>
<td>.032 (.000)</td>
</tr>
<tr>
<td>F</td>
<td>-.537 (.033)</td>
<td>.073 (.000)</td>
</tr>
</tbody>
</table>
Table 6.2. Locations and latitude of acceptance parameter values of the SSLM (general version, retest)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.872 (.031)</td>
<td>.149 (.001)</td>
</tr>
<tr>
<td>B</td>
<td>.328 (.033)</td>
<td>.072 (.000)</td>
</tr>
<tr>
<td>C</td>
<td>-.048 (.033)</td>
<td>.062 (.000)</td>
</tr>
<tr>
<td>D</td>
<td>-.150 (.037)</td>
<td>.006 (.000)</td>
</tr>
<tr>
<td>E</td>
<td>-.385 (.036)</td>
<td>.055 (.000)</td>
</tr>
<tr>
<td>F</td>
<td>-.617 (.037)</td>
<td>.069 (.000)</td>
</tr>
</tbody>
</table>

For the general version of the Subjective Control scales, the SSLM produced identical locations for statements C & D (Table 6.1). This did not occur, however, in the re-test condition (Table 6.2), where the SSLM produced the order upon the statements predicted by the ordinal determinable (Michell, 1994). Under both test and re-test conditions, statement D had the smallest latitude of acceptance whilst statement A had the greatest.

Table 6.3. Locations and latitude of acceptance parameter values of the HCM (general version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.553 (.027)</td>
<td>.286 (.005)</td>
</tr>
<tr>
<td>B</td>
<td>.726 (.026)</td>
<td>.169 (.004)</td>
</tr>
<tr>
<td>C</td>
<td>-.348 (.029)</td>
<td>.133 (.005)</td>
</tr>
<tr>
<td>D</td>
<td>-.197 (.032)</td>
<td>.044 (.008)</td>
</tr>
<tr>
<td>E</td>
<td>-.608 (.029)</td>
<td>.109 (.005)</td>
</tr>
<tr>
<td>F</td>
<td>-.1.127 (.029)</td>
<td>.170 (.005)</td>
</tr>
</tbody>
</table>

Table 6.4. Locations and latitude of acceptance parameter values of the HCM (general version, retest)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.714 (.029)</td>
<td>.311 (.005)</td>
</tr>
<tr>
<td>B</td>
<td>.653 (.027)</td>
<td>.164 (.004)</td>
</tr>
<tr>
<td>C</td>
<td>-.098 (.027)</td>
<td>.150 (.004)</td>
</tr>
<tr>
<td>D</td>
<td>-.230 (.031)</td>
<td>.164 (.004)</td>
</tr>
<tr>
<td>E</td>
<td>-.753 (.031)</td>
<td>.135 (.005)</td>
</tr>
<tr>
<td>F</td>
<td>-.1.286 (.033)</td>
<td>.165 (.005)</td>
</tr>
</tbody>
</table>

Like the SSLM, the HCM did not produce in the test condition the statement order predicted by the ordinal determinable (Table 6.3). However, the HCM did not produce identical locations for statements C & D. Instead, it located Statement C on the continuum as closer toward Statement F than Statement D. Similarly to the SSLM, however, the HCM produced the statement order predicted by the ordinal determinable
(Michell, 1994a) under the re-test condition (Table 6.4). Statement A had again the
greatest latitude of acceptance in both conditions. Statement D had the smallest in the test
condition as did Statement E in the re-test condition. Latitude of acceptance parameters
were greater overall in the re-test condition.

The PARELLA model did not produce the statement order predicted by the ordinal
determinable under either the test or re-test conditions (Tables 6.5 & 6.6).

Table 6.5. Locations and latitude of acceptance parameter values of the PARELLA model (general version )

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.109 (.029)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>B</td>
<td>3.603 (.031)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>C</td>
<td>-.075 (.035)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>D</td>
<td>-2.832 (.075)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>E</td>
<td>-2.198 (.056)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>F</td>
<td>-1.607 (.043)</td>
<td>.400 (.000)</td>
</tr>
</tbody>
</table>

Table 6.6. Locations and latitude of acceptance parameter values of the PARELLA model (general version, retest ).

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.488 (.021)</td>
<td>.389 (.012)</td>
</tr>
<tr>
<td>B</td>
<td>5.574 (.090)</td>
<td>.807 (.019)</td>
</tr>
<tr>
<td>C</td>
<td>-2.782 (.081)</td>
<td>.661 (.016)</td>
</tr>
<tr>
<td>D</td>
<td>-3.408 (.089)</td>
<td>.554 (.014)</td>
</tr>
<tr>
<td>E</td>
<td>-1.338 (.042)</td>
<td>.294 (.009)</td>
</tr>
<tr>
<td>F</td>
<td>-.0534 (.012)</td>
<td>.121 (.005)</td>
</tr>
</tbody>
</table>

Table 6.7. Locations and latitude of acceptance parameter values of the SSLM (time involvement version).

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.778 (.031)</td>
<td>.134 (.001)</td>
</tr>
<tr>
<td>B</td>
<td>.364 (.034)</td>
<td>.063 (.000)</td>
</tr>
<tr>
<td>C</td>
<td>-.019 (.034)</td>
<td>.053 (.000)</td>
</tr>
<tr>
<td>D</td>
<td>-.287 (.038)</td>
<td>.005 (.000)</td>
</tr>
<tr>
<td>E</td>
<td>-.245 (.035)</td>
<td>.057 (.000)</td>
</tr>
<tr>
<td>F</td>
<td>-.491 (.036)</td>
<td>.055 (.000)</td>
</tr>
</tbody>
</table>
Table 6.8. Locations and latitude of acceptance parameter values of the SSLM (time involvement version, retest)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.845 (.030)</td>
<td>.154 (.001)</td>
</tr>
<tr>
<td>B</td>
<td>.329 (.033)</td>
<td>.077 (.000)</td>
</tr>
<tr>
<td>C</td>
<td>-.010 (.033)</td>
<td>.071 (.000)</td>
</tr>
<tr>
<td>D</td>
<td>-.336 (.037)</td>
<td>.039 (.000)</td>
</tr>
<tr>
<td>E</td>
<td>-.292 (.036)</td>
<td>.046 (.000)</td>
</tr>
<tr>
<td>F</td>
<td>-.536 (.037)</td>
<td>.062 (.000)</td>
</tr>
</tbody>
</table>

For the time involvement version of the Subjective Control scales, the SSLM did not produce the statement order predicted by the ordinal determinable (Michell, 1998) under either the test or re-test conditions (Tables 6.8 & 6.9). In both conditions, the SSLM located Statement D as being closer to Statement F than Statement E. In both test and re-test conditions, Statement A had the largest latitude of acceptance and Statement D the smallest. This is similar to what was discovered for the SSLM of the general version.

Table 6.9. Locations and latitude of acceptance parameter values of the HCM (time involvement version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.482 (.027)</td>
<td>.265 (.005)</td>
</tr>
<tr>
<td>B</td>
<td>.750 (.027)</td>
<td>.149 (.004)</td>
</tr>
<tr>
<td>C</td>
<td>.009 (.028)</td>
<td>.135 (.004)</td>
</tr>
<tr>
<td>D</td>
<td>-.511 (.031)</td>
<td>.085 (.006)</td>
</tr>
<tr>
<td>E</td>
<td>-.717 (.029)</td>
<td>.149 (.005)</td>
</tr>
<tr>
<td>F</td>
<td>-1.014 (.030)</td>
<td>.148 (.005)</td>
</tr>
</tbody>
</table>

Table 6.10. Locations and latitude of acceptance parameter values of the HCM (time involvement version, retest)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.736 (.029)</td>
<td>.337 (.005)</td>
</tr>
<tr>
<td>B</td>
<td>.599 (.027)</td>
<td>.166 (.004)</td>
</tr>
<tr>
<td>C</td>
<td>-.032 (.027)</td>
<td>.156 (.004)</td>
</tr>
<tr>
<td>D</td>
<td>-.641 (.032)</td>
<td>.111 (.005)</td>
</tr>
<tr>
<td>E</td>
<td>-.573 (.031)</td>
<td>.121 (.005)</td>
</tr>
<tr>
<td>F</td>
<td>-1.089 (.033)</td>
<td>.143 (.005)</td>
</tr>
</tbody>
</table>

Unlike the SSLM, the HCM for the time involvement version of the Subjective Control scales did produce a statement order consistent with that predicted by the ordinal determinable (Michell, 1994). This occurred in both the test and re-test conditions.
(Tables 6.9 & 6.10). As for the SSLM, however, Statement A had the largest latitude of acceptance and Statement D the smallest across both conditions.

Table 6.11. Locations and latitude of acceptance parameter values of the SSLM (impulses version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.787 (.029)</td>
<td>.029 (.001)</td>
</tr>
<tr>
<td>B</td>
<td>.254 (.033)</td>
<td>.033 (.000)</td>
</tr>
<tr>
<td>C</td>
<td>.062 (.034)</td>
<td>.034 (.000)</td>
</tr>
<tr>
<td>D</td>
<td>-.145 (.036)</td>
<td>.036 (.000)</td>
</tr>
<tr>
<td>E</td>
<td>-.357 (.037)</td>
<td>.037 (.000)</td>
</tr>
<tr>
<td>F</td>
<td>-.600 (.037)</td>
<td>.037 (.000)</td>
</tr>
</tbody>
</table>

Table 6.12. Locations and latitude of acceptance parameter values of the SSLM (impulses version, retest)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.815 (.030)</td>
<td>.164 (.001)</td>
</tr>
<tr>
<td>B</td>
<td>.263 (.033)</td>
<td>.076 (.000)</td>
</tr>
<tr>
<td>C</td>
<td>.022 (.035)</td>
<td>.035 (.000)</td>
</tr>
<tr>
<td>D</td>
<td>-.190 (.037)</td>
<td>.011 (.000)</td>
</tr>
<tr>
<td>E</td>
<td>-.332 (.037)</td>
<td>.040 (.000)</td>
</tr>
<tr>
<td>F</td>
<td>-.578 (.037)</td>
<td>.062 (.001)</td>
</tr>
</tbody>
</table>

The SSLM for the impulses to gamble version of the Subjective Control scales located the statements upon a continuum in a manner consistent with the statement order predicted by the ordinal determinable (Michell, 1994). In the test condition, the SSLM produced latitude of acceptance parameters of very similar magnitude for all statements (Table 6.11). This is unlike the SSLM models for the general and time involvement versions. In the re-test condition (Table 6.12), however, Statement A had the largest latitude of acceptance and Statement E the smallest.

Table 6.13. Locations and latitude of acceptance parameter values of the HCM (impulses version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.568 (.028)</td>
<td>.310 (.005)</td>
</tr>
<tr>
<td>B</td>
<td>.471 (.027)</td>
<td>.150 (.004)</td>
</tr>
<tr>
<td>C</td>
<td>.111 (.027)</td>
<td>.122 (.004)</td>
</tr>
<tr>
<td>D</td>
<td>-.283 (.029)</td>
<td>.104 (.005)</td>
</tr>
<tr>
<td>E</td>
<td>-.669 (.030)</td>
<td>.108 (.005)</td>
</tr>
<tr>
<td>F</td>
<td>-1.197 (.031)</td>
<td>.140 (.005)</td>
</tr>
</tbody>
</table>
The HCM for the impulses to gamble version also located the statements upon a continuum in a manner consistent with the statement order predicted by the ordinal determinable. Statements A & D had the largest and smallest latitude of acceptance parameters, respectively (Tables 6.13 & 6.14).

### 6.6.2 Criterion, concurrent & discriminative validity and internal reliability

Criterion (or predictive) validity was tested by calculating Pearson’s product – moment correlations between the person location estimates and frequency of gambling play and expenditure per session of play excluding winnings. Concurrent validity was tested by calculating the same coefficients between the person location estimates and both versions of the SGC (Baron et al, 1995; O' Connor, 2000). The results of these analyses are presented in Tables 6.15 to 6.17. The coefficients were found to be negative, statistically significant and moderate to strong in magnitude.
Table 6.16. Correlations between criterion variables and person locations of the time involvement version.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Test phase</th>
<th>Retest phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SSLM</td>
<td>HCM</td>
</tr>
<tr>
<td>Frequency</td>
<td>-.306**</td>
<td>-.338**</td>
</tr>
<tr>
<td>Expenditure</td>
<td>-.336**</td>
<td>-.369**</td>
</tr>
<tr>
<td>18 item SGC</td>
<td>-.633**</td>
<td>-.622**</td>
</tr>
<tr>
<td>12 item SGC</td>
<td>-.687**</td>
<td>-.694**</td>
</tr>
</tbody>
</table>

**p < .01, two tailed

Table 6.17. Correlations between criterion variables and person locations of the urges to gamble version

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Test phase</th>
<th>Retest phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SSLM</td>
<td>HCM</td>
</tr>
<tr>
<td>Frequency</td>
<td>-.357**</td>
<td>-.353**</td>
</tr>
<tr>
<td>Expenditure</td>
<td>-.418**</td>
<td>-.395**</td>
</tr>
<tr>
<td>18 item SGC</td>
<td>-.693**</td>
<td>-.683**</td>
</tr>
<tr>
<td>12 item SGC</td>
<td>-.753**</td>
<td>-.724**</td>
</tr>
</tbody>
</table>

**p < .01, two tailed

Descriptive validity and internal test reliability were conducted on the person location estimates using the pertinent facilities in the RATEfold software. Descriptive validity was tested by performing a one-way Analysis of Variance (ANOVA) procedure upon the person locations for each version of the Subjective Control scales and for both the SSLM and HCM unfolding models. The software could not perform the calculations using the PARELLA model. Post-hoc comparisons for each ANOVA were calculated by hand using Fischer's protected t-test. Fisher's method was chosen as there were uneven numbers of participants in each subject group (Heiman, 1992).

Internal test reliability was calculated by the RATEfold program using the Person Separation Index (PSI). The PSI is the Rasch IRT equivalent of Cronbach's alpha in classical test theory (Andrich, Lyne, Sheridan & Luo, 2001) and is given by the equation:

\[ r_p = \frac{\hat{\sigma}_B^2 - \hat{\sigma}_e^2}{\hat{\sigma}_B^2} \]

where \( \hat{\sigma}_B^2 = \frac{\sum_{v=1}^{N} (\hat{\beta}_v - \bar{\beta})^2}{N - 1} \) is the estimated variance of the person location estimates, with \( N \) the total number of persons \( v \) in the sample; \( \hat{\beta}_v \) the location estimate for each person \( v \); and \( \bar{\beta} \) the mean person location. \( \hat{\sigma}_e^2 = \frac{\sum_{v=1}^{N} \hat{\sigma}_e^2}{N} \) is the mean of the squared standard errors of measurement of all persons \( v \).
The RATEfold software calculated the PSI for each participant group as well an overall figure. The results are presented in Tables 6.18 – 6.29. The columns in each table present the number of persons in each group of participants, the mean person location for each group, the standard deviation of the group person locations, the PSI for each group, and the F ratio of the one way Analysis of Variance (ANOVA) conducted on the person locations across the three groups of participants.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>PSI</th>
<th>ANOVA F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>57</td>
<td>.617</td>
<td>.524</td>
<td>.011</td>
<td></td>
</tr>
<tr>
<td>Club</td>
<td>99</td>
<td>.413</td>
<td>.412</td>
<td>.007</td>
<td></td>
</tr>
<tr>
<td>Problem</td>
<td>49</td>
<td>-.487</td>
<td>.361</td>
<td>.003</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>205</td>
<td>.255</td>
<td>.608</td>
<td>.012</td>
<td>96.032**</td>
</tr>
</tbody>
</table>

**p < .01

For the SSLM of the general version of the Subjective Control scales, the PSI values for each of the participant group and the total PSI were very low, indicating very low internal reliability (Table 6.18). The ANOVA suggested that there was a significant difference among the mean person locations of each of three groups. Post-hoc comparisons were then undertaken using Fischer’s protected t-test. It was found that the mean person locations between the club and student gamblers ($t_{(202)} = 2.8, p < .01$) and the club and problem gamblers ($t_{(202)} = 12.93, p < .01$) differed significantly. It was also found that the mean person locations between the student and problem gamblers differed significantly ($t_{(202)} = 11.76, p < .01$).

A high total PSI value was found, however, in the data from the retest condition (Table 6.19). The PSI for the student and problem groups remained low. Statistically significant differences were found between the mean person locations of the club and student groups, club and problem groups and student and problem groups ($t_{(201)} = 1.99, p < .05$; $t_{(201)} = 13.35, p < .01$; $t_{(201)} = 13.67, p < .01$, respectively).

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>PSI</th>
<th>ANOVA F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>57</td>
<td>.724</td>
<td>.411</td>
<td>.482</td>
<td></td>
</tr>
<tr>
<td>Club</td>
<td>99</td>
<td>.575</td>
<td>.516</td>
<td>.601</td>
<td></td>
</tr>
<tr>
<td>Problem</td>
<td>48</td>
<td>-.480</td>
<td>.311</td>
<td>.409</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>204</td>
<td>.368</td>
<td>.652</td>
<td>.715</td>
<td>113.533**</td>
</tr>
</tbody>
</table>

**p < .01
For the HCM of the general version of the Subjective Control scales, the PSI values for each of the participant group and the total PSI were extremely low, indicating extremely low internal reliability (Table 6.20). The zero PSI value for the problem gambler participant group suggested that the scale was completely unreliable. The ANOVA suggested that there was a significant difference among the mean person locations of each of three groups. Post-hoc comparisons found that the mean person locations between the club and student gamblers ($t(202) = 2.81, p < .01$) and the club and problem gamblers ($t(202) = 11.84, p < .01$) differed significantly. It was also found that the mean person locations between the student and problem gamblers differed significantly ($t(202) = 13.02, p < .01$).

In contrast, very high PSI values were found in the data from the retest condition (Table 6.21). Statistically significant differences were found between the mean person locations of the club and student groups, club and problem groups and student and problem groups ($t(201) = 2.21, p < .05; t(201) = 13.52, p < .01; t(201) = 14.01, p < .01$, respectively).

**Table 6.20. Mean group person location and PSI of the HCM of the general version.**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>PSI</th>
<th>ANOVA F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>57</td>
<td>1.168</td>
<td>.964</td>
<td>.037</td>
<td></td>
</tr>
<tr>
<td>Club</td>
<td>99</td>
<td>.787</td>
<td>.772</td>
<td>.023</td>
<td></td>
</tr>
<tr>
<td>Problem</td>
<td>49</td>
<td>-.900</td>
<td>.676</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>205</td>
<td>.490</td>
<td>1.135</td>
<td>.005</td>
<td>97.385**</td>
</tr>
</tbody>
</table>

** $p < .01$

**Table 6.21. Mean group person location and PSI of the HCM of the general version (retest phase).**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>PSI</th>
<th>ANOVA F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>57</td>
<td>1.454</td>
<td>.842</td>
<td>.821</td>
<td></td>
</tr>
<tr>
<td>Club</td>
<td>99</td>
<td>1.129</td>
<td>1.006</td>
<td>.876</td>
<td></td>
</tr>
<tr>
<td>Problem</td>
<td>48</td>
<td>-.978</td>
<td>.598</td>
<td>.78</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>204</td>
<td>.724</td>
<td>1.298</td>
<td>.925</td>
<td>118.227**</td>
</tr>
</tbody>
</table>

** $p < .01$

**Table 6.22. Mean group person location and PSI of the SSLM of the time involvement version.**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>PSI</th>
<th>ANOVA F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>57</td>
<td>.613</td>
<td>.423</td>
<td>.510</td>
<td></td>
</tr>
<tr>
<td>Club</td>
<td>102</td>
<td>.465</td>
<td>.576</td>
<td>.660</td>
<td></td>
</tr>
<tr>
<td>Problem</td>
<td>48</td>
<td>-.373</td>
<td>.309</td>
<td>.386</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>207</td>
<td>.312</td>
<td>.617</td>
<td>.695</td>
<td>63.079**</td>
</tr>
</tbody>
</table>

** $p < .01$
For the SSM of the time involvement version of the Subjective Control scales, the PSI values for each of the participant group and the total PSI were moderate, indicating moderate internal reliability (Table 6.22). The ANOVA suggested that there was a significant difference among the mean person locations of each of three groups. Post-hoc comparisons found that the mean person locations between the club and student gamblers ($t(204) = 1.83, p < .05$) and the club and problem gamblers ($t(204) = 9.81, p < .01$) differed significantly. It was also found that the mean person locations between the student and problem gamblers differed significantly ($t(204) = 10.32, p < .01$).

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>PSI</th>
<th>ANOVA F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>57</td>
<td>.712</td>
<td>.424</td>
<td>.505</td>
<td></td>
</tr>
<tr>
<td>Club</td>
<td>98</td>
<td>.533</td>
<td>.555</td>
<td>.630</td>
<td></td>
</tr>
<tr>
<td>Problem</td>
<td>47</td>
<td>-.444</td>
<td>.301</td>
<td>.397</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>202</td>
<td>.356</td>
<td>.649</td>
<td>.713</td>
<td>89.843**</td>
</tr>
</tbody>
</table>

** $p < .01$

Moderate PSI values were also found in the data from the retest condition (Table 6.23). Statistically significant differences were found between the mean person locations of the club and student groups, club and problem groups and student and problem groups ($t(199) = 2.27, p < .05$; $t(199) = 11.61, p < .01$; $t(199) = 12.37, p < .01$, respectively).

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>PSI</th>
<th>ANOVA F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>57</td>
<td>1.248</td>
<td>.847</td>
<td>.841</td>
<td></td>
</tr>
<tr>
<td>Club</td>
<td>102</td>
<td>.983</td>
<td>1.080</td>
<td>.902</td>
<td></td>
</tr>
<tr>
<td>Problem</td>
<td>48</td>
<td>-.741</td>
<td>.598</td>
<td>.774</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>207</td>
<td>.656</td>
<td>1.207</td>
<td>.921</td>
<td>71.778**</td>
</tr>
</tbody>
</table>

** $p < .01$

For the HCM of the time involvement version of the Subjective Control scales, the PSI values for each of the participant group and the total PSI were high, indicating strong internal reliability (Table 6.24). The ANOVA suggested that there was a significant difference among the mean person locations of each of three groups. Post-hoc comparisons found that the mean person locations between the club and student gamblers ($t(204) = 1.72, p < .05$) and the club and problem gamblers ($t(204) = 10.57, p < .01$) differed significantly. It was also found that the mean person locations between the student and problem gamblers differed significantly ($t(204) = 10.90, p < .01$).
Table 6.25. Mean group person location and PSI of the HCM of the time involvement version (retest condition).

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>PSI</th>
<th>ANOVA F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>57</td>
<td>1.372</td>
<td>.828</td>
<td>.817</td>
<td></td>
</tr>
<tr>
<td>Club</td>
<td>98</td>
<td>.989</td>
<td>1.078</td>
<td>.886</td>
<td></td>
</tr>
<tr>
<td>Problem</td>
<td>47</td>
<td>-.896</td>
<td>.574</td>
<td>.768</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>202</td>
<td>.658</td>
<td>1.262</td>
<td>.92</td>
<td>90.632**</td>
</tr>
</tbody>
</table>

**p < .01

Strong PSI values were also found in the data from the retest condition (Table 6.25). Statistically significant differences were found between the mean person locations of the club and student groups, club and problem groups and student and problem groups ($t(199) = 2.50, p < .01; t(199) = 11.55, p < .01; t(199) = 12.52, p < .01$, respectively).

Table 6.26. Mean group person location and PSI of the SSLM of the urges to gamble version.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>PSI</th>
<th>ANOVA F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>57</td>
<td>.579</td>
<td>.457</td>
<td>.538</td>
<td></td>
</tr>
<tr>
<td>Club</td>
<td>102</td>
<td>.405</td>
<td>.536</td>
<td>.624</td>
<td></td>
</tr>
<tr>
<td>Problem</td>
<td>48</td>
<td>-.544</td>
<td>.285</td>
<td>.141</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>207</td>
<td>.233</td>
<td>.637</td>
<td>.619</td>
<td>87.965**</td>
</tr>
</tbody>
</table>

**p < .01

For the SSLM of the impulses to gamble version of the Subjective Control scales, the PSI values for each of the participant group and the total PSI were moderate, indicating moderate internal reliability (Table 6.26). The PSI value for the problem group, however, was very low. The ANOVA suggested that there was a significant difference among the mean person locations of each of three groups. Post-hoc comparisons found that the mean person locations between the club and student gamblers ($t(204) = 2.24$, $p < .05$) and the club and problem gamblers ($t(204) = 11.53, p < .01$) differed significantly. It was also found that the mean person locations between the student and problem gamblers differed significantly ($t(204) = 12.30, p < .01$).

Table 6.27. Mean group person location and PSI of the SSLM of the urges to gamble version (retest phase).

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>PSI</th>
<th>ANOVA F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>57</td>
<td>.650</td>
<td>.473</td>
<td>.547</td>
<td></td>
</tr>
<tr>
<td>Club</td>
<td>99</td>
<td>.499</td>
<td>.550</td>
<td>.621</td>
<td></td>
</tr>
<tr>
<td>Problem</td>
<td>47</td>
<td>-.512</td>
<td>.287</td>
<td>.127</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>203</td>
<td>.307</td>
<td>.660</td>
<td>.615</td>
<td>89.951**</td>
</tr>
</tbody>
</table>

**p < .01

210
Moderate PSI values were also found in the data from the retest condition (Table 6.27). The PSI value for the problem gambler group, however, was even lower than in the test condition. Statistically significant differences were found between the mean person locations of the club and student groups, club and problem groups and student and problem groups ($t_{(200)} = 1.88, p < .01$; $t_{(200)} = 11.82, p < .01$; $t_{(200)} = 12.21, p < .01$, respectively).

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>PSI</th>
<th>ANOVA F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>57</td>
<td>1.095</td>
<td>.871</td>
<td>.845</td>
<td></td>
</tr>
<tr>
<td>Club</td>
<td>102</td>
<td>.763</td>
<td>1.046</td>
<td>.893</td>
<td></td>
</tr>
<tr>
<td>Problem</td>
<td>48</td>
<td>-1.070</td>
<td>.536</td>
<td>.308</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>207</td>
<td>.430</td>
<td>1.230</td>
<td>.857</td>
<td>87.471**</td>
</tr>
</tbody>
</table>

** $p < .01$

For the HCM of the impulses to gamble version of the Subjective Control scales, the PSI values for each of the participant group and the total PSI were relatively high, indicating moderate internal reliability (Table 6.28). The PSI value for the problem group, however, was moderate, reflecting the findings of the SSLM. The ANOVA suggested that there was a significant difference among the mean person locations of each of three groups. Post-hoc comparisons found that the mean person locations between the club and student gamblers ($t_{(204)} = 14.70, p < .01$) and the club and problem gamblers ($t_{(204)} = 72.43, p < .01$) differed significantly. It was also found that the mean person locations between the student and problem gamblers differed significantly ($t_{(204)} = 68.30, p < .01$).

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>PSI</th>
<th>ANOVA F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>57</td>
<td>1.184</td>
<td>.880</td>
<td>.837</td>
<td></td>
</tr>
<tr>
<td>Club</td>
<td>99</td>
<td>.937</td>
<td>.997</td>
<td>.873</td>
<td></td>
</tr>
<tr>
<td>Problem</td>
<td>47</td>
<td>-.945</td>
<td>.535</td>
<td>.225</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>203</td>
<td>.570</td>
<td>1.213</td>
<td>.812</td>
<td>91.417**</td>
</tr>
</tbody>
</table>

** $p < .01$

Moderate PSI values were also found in the data from the retest condition (Table 6.29). The PSI value for the problem gambler group, however, was even lower than in the test condition. Statistically significant differences were found between the mean person locations of the club and student groups, club and problem groups and student and problem groups ($t_{(200)} = 11.45, p < .01$; $t_{(200)} = 12.03, p < .01$; $t_{(200)} = 12.23, p < .01$, respectively).
6.6.3 Item locations & tests of fit of the SHCM paired comparison model

Analyses conducted using the simple hyperbolic cosine model (SHCM) (Andrich & Luo, 1993) differed from those conducted on the rating scale data. The RUMMfold computer program, however, did not have the facility for analysing responses made to bilateral paired comparison tasks. The program will compute item locations for \( n \) statements if and only if \( n(n-1)/2 \) paired comparison tasks have been undertaken by study participants. As bilateral paired comparison tasks assume that the basic argument of Coombs's (1964) hold true (viz., the distances between statements are quantitative like points on a line), a minimum of 5 and maximum of 6 paired comparison tasks were undertaken by participants of the present study. Each participant, however, did indicate before undertaking the paired comparison tasks which statement out of the six statements was the preferred statement. This preferred statement was used to derive the remaining unilateral paired comparison tasks. These data for each of the three questionnaires were analysed by the RUMMfold program.

Tables 6.30, 6.32 & 6.34 display the results of the SHCM analyses for the general, time involvement and impulses to gamble versions of the Subjective Control scales. The columns of each table contain the statement location estimates (in logits) in the test condition, the standard errors for these estimates, the statement location estimates (also in logits) in the retest condition and the standard errors for these estimates. It must be noted that the RUMMfold program sets \( \theta = \ln 2 \approx .693 \).

Tables 6.31, 6.33 & 6.35 display the tests of fit of the paired comparison SHCM to the data of the general, time involvement and impulses to gamble versions, respectively. The chi-square values above the diagonal are those for each paired comparison undertaken in the test condition. Below the diagonal are those for the paired comparisons undertaken in the retest condition. The bottom two rows in each of these tables contains the chi-square values for the overall test of fit to the SHCM in both the test and re-test condition.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (test)</th>
<th>S.E</th>
<th>Location (retest)</th>
<th>S.E</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6.751</td>
<td>.170</td>
<td>6.606</td>
<td>.175</td>
</tr>
<tr>
<td>B</td>
<td>4.237</td>
<td>.155</td>
<td>4.040</td>
<td>.165</td>
</tr>
<tr>
<td>C</td>
<td>1.432</td>
<td>.165</td>
<td>1.511</td>
<td>.163</td>
</tr>
<tr>
<td>D</td>
<td>-1.463</td>
<td>.173</td>
<td>-1.298</td>
<td>.162</td>
</tr>
<tr>
<td>E</td>
<td>-3.844</td>
<td>.169</td>
<td>-3.867</td>
<td>.181</td>
</tr>
<tr>
<td>F</td>
<td>-7.112</td>
<td>.242</td>
<td>-6.993</td>
<td>.233</td>
</tr>
</tbody>
</table>
Table 6.31. Overall and paired comparison tests of fit of the SHCM to the general version.

<table>
<thead>
<tr>
<th>Statement</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.48</td>
<td>.04</td>
<td></td>
<td>180.33**</td>
<td>86.05**</td>
<td>6.57</td>
</tr>
<tr>
<td>B</td>
<td>1.43</td>
<td>2.48</td>
<td></td>
<td>15.13**</td>
<td>8.69*</td>
<td>.32</td>
</tr>
<tr>
<td>C</td>
<td>2.58</td>
<td>.12</td>
<td></td>
<td>4.99</td>
<td>.60</td>
<td>.36</td>
</tr>
<tr>
<td>D</td>
<td>87.69**</td>
<td>16.63**</td>
<td></td>
<td>2.93</td>
<td>1.85</td>
<td>6.80</td>
</tr>
<tr>
<td>E</td>
<td>158.58**</td>
<td>16.01**</td>
<td>1.36</td>
<td>.31</td>
<td></td>
<td>1.71</td>
</tr>
<tr>
<td>F</td>
<td>16.12**</td>
<td>1.24</td>
<td>.11</td>
<td>5.56</td>
<td>1.61</td>
<td></td>
</tr>
</tbody>
</table>

Overall chi-square (test phase) = 312.259**
Overall chi-square (retest phase) = 316.4**

**p < .01, *p < .05

The SHCM for the general version of the Subjective Control scales (Table 6.30) produced an order upon the statement locations consistent with that predicted by the ordinal determinable (Michell, 1994). Some of the paired comparisons fitted the model very well (Table 6.31). Those pairs that did not fit the model were statement pairs AD, AE, BD & BE. In the re-test phase, the the statement pair AF did not fit the model. The overall measures of fit in both the test and re-test conditions displayed large values and were highly statistically significant, suggesting a poor fit of the data overall to the SHCM model.

Table 6.32: Test and retest phase statement locations and standard errors (time involvement version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (test)</th>
<th>S.E</th>
<th>Location (retest)</th>
<th>S.E</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6.997</td>
<td>.175</td>
<td>7.493</td>
<td>.183</td>
</tr>
<tr>
<td>B</td>
<td>4.338</td>
<td>.171</td>
<td>4.571</td>
<td>.190</td>
</tr>
<tr>
<td>C</td>
<td>1.067</td>
<td>.162</td>
<td>1.438</td>
<td>.178</td>
</tr>
<tr>
<td>D</td>
<td>-1.546</td>
<td>.158</td>
<td>-1.512</td>
<td>.187</td>
</tr>
<tr>
<td>E</td>
<td>-3.961</td>
<td>.162</td>
<td>-4.487</td>
<td>.193</td>
</tr>
<tr>
<td>F</td>
<td>-6.893</td>
<td>.212</td>
<td>-7.503</td>
<td>.239</td>
</tr>
</tbody>
</table>

213
Table 6.33. Overall and paired comparison tests of fit of the SHCM to the time involvement version

<table>
<thead>
<tr>
<th>Statement</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.56</td>
<td>.06</td>
<td>283.82**</td>
<td>359.44**</td>
<td>21.60**</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>.36</td>
<td>30.31**</td>
<td>27.93**</td>
<td>1.95</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1.06</td>
<td>.37</td>
<td>2.44</td>
<td>1.38</td>
<td>.09</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>245.81**</td>
<td>19.01**</td>
<td>2.</td>
<td>.33</td>
<td>3.82</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>127.47**</td>
<td>14.18**</td>
<td>.65</td>
<td>.19</td>
<td>.77</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>15.40**</td>
<td>1.62</td>
<td>.22</td>
<td>3.46</td>
<td>1.05</td>
<td></td>
</tr>
</tbody>
</table>

Overall chi-square (test phase) = 434.022**
Overall chi-square (retest phase) = 734.863**

** p < .01, * p < .05

The SHCM for the time involvement version of the Subjective Control scales (Table 6.32) produced an order upon the statement locations consistent with that predicted by the ordinal determinable (Michell, 1994). The SHCM fitted some of the paired comparisons very well (Table 6.33). Those pairs which did not fit the model were the pairs AD, AE, AF, BD & BE. The SHCM also did not fit these individual pairs in the re-test condition. The overall measures of fit in both the test and re-test conditions displayed large values and were highly statistically significant, suggesting a poor fit of the data overall to the SHCM.

Table 6.34: Test and retest phase statement locations and standard errors (urges to gamble version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (test)</th>
<th>S.E</th>
<th>Location (retest)</th>
<th>S.E</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6.444</td>
<td>.161</td>
<td>6.453</td>
<td>.180</td>
</tr>
<tr>
<td>B</td>
<td>4.031</td>
<td>.151</td>
<td>3.631</td>
<td>.164</td>
</tr>
<tr>
<td>C</td>
<td>1.526</td>
<td>.156</td>
<td>1.282</td>
<td>.158</td>
</tr>
<tr>
<td>D</td>
<td>-1.250</td>
<td>.152</td>
<td>-1.363</td>
<td>.151</td>
</tr>
<tr>
<td>F</td>
<td>-6.995</td>
<td>.231</td>
<td>-6.268</td>
<td>.204</td>
</tr>
</tbody>
</table>
Table 6.35. Overall and paired choice tests of fit for Table 6.34 (test phase chi squares below diagonal)

<table>
<thead>
<tr>
<th>Statement</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.89</td>
<td>.95</td>
<td>52.20**</td>
<td>1.65.83**</td>
<td>48.91**</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>.59</td>
<td>1.60</td>
<td>5.78</td>
<td>13.79**</td>
<td>1.43</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>2.90</td>
<td>1.04</td>
<td>2.54</td>
<td>1.76</td>
<td>1.80</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>39.68**</td>
<td>7.16</td>
<td>1.05</td>
<td>2.64</td>
<td>2.17</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>357.99**</td>
<td>44.87**</td>
<td>4.10</td>
<td>5.30</td>
<td>.71</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>70.60**</td>
<td>4.50**</td>
<td>.10</td>
<td>1.52</td>
<td>2.67</td>
<td></td>
</tr>
</tbody>
</table>

Overall chi-square (test phase) = 544.086**
Overall chi-square (retest phase) = 302.999**

**p < .01, *p <.05

The SHCM for the general version of the Subjective Control scales (Table 6.34) produced an order upon the statement locations consistent with that predicted by the ordinal determinable (Michell, 1994). Some of the paired comparisons fitted the model very well (Table 6.35). Those pairs that did not fit the model were statement pairs AD, AE, AF & BE. In the re-test phase, the statement pair BF did not fit the model. The overall measures of fit in both the test and re-test conditions displayed large values and were highly statistically significant, suggesting a poor fit of the data overall to the SHCM model.

Table 6.36. Pearson’s r correlations between criterion variables and SHCM person location estimates.

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>Frequency of play</th>
<th>Session expenditure</th>
<th>18 item SGC</th>
<th>12 item SGC</th>
</tr>
</thead>
<tbody>
<tr>
<td>General (test)</td>
<td>-3.87**</td>
<td>-3.74**</td>
<td>-.690**</td>
<td>-.792**</td>
</tr>
<tr>
<td>General (retest)</td>
<td>-.409**</td>
<td>-.340**</td>
<td>-.735**</td>
<td>-.830**</td>
</tr>
<tr>
<td>Time Limit (test)</td>
<td>-.370**</td>
<td>-.357**</td>
<td>-.703**</td>
<td>-.813**</td>
</tr>
<tr>
<td>Time Limit (retest)</td>
<td>-.387**</td>
<td>-.381**</td>
<td>-.723**</td>
<td>-.794**</td>
</tr>
<tr>
<td>Impulsivity (test)</td>
<td>-.356**</td>
<td>-.405**</td>
<td>-.680**</td>
<td>-.792**</td>
</tr>
<tr>
<td>Impulsivity (retest)</td>
<td>-.398**</td>
<td>-.367**</td>
<td>-.722**</td>
<td>-.805**</td>
</tr>
</tbody>
</table>

**p < .01, two tailed.

Table 6.36 displays the Pearson’s r product moment correlation coefficients between the person location estimates of all three scale versions and the criterion variables of frequency of play and session expenditure. It also displays the correlation coefficients between the person location estimates and the total person scores on both versions of the SGC (Baron, et al, 1995). Similar to the findings of Chapter 5, the person location estimates of the SHCM across all scale versions correlated only moderately with the criterion variables. The person estimates were correlated strongly with the total person SGC score for both versions of the SGC. This suggests that the Subjective Control scales exhibit strong concurrent validity.
6.7 Comparisons of the ordered metric information between the axiomatic and probabilistic scaling solutions

Chapter 5 attempted to derive interval scale solutions for each of the Subjective Control questionnaires via the cancellation conditions of axiomatic conjoint measurement (Krantz et al, 1971). It was not assumed that subjective control was quantitative or unidimensional. The present chapter attempted to derive interval scale solutions for each of the Subjective Control questionnaires via continuous mathematical functions relating observed item response proportions to latent, logistic continua. It was assumed, however, as a result of the earlier analyses that subjective control was quantitative.

The striking finding from both chapters is that generally speaking the order of the statements was successfully retrieved from the data. This purely ordinal information strongly supports the method of statement construction (viz., the theory of the ordinal determinable (Michell, 1994a, 1998)). But the derived scaling solutions in themselves do not constitute very strong evidence in favour of the measurability of subjective control. Comparisons, however, between the interstimulus intervals created by both types of scaling solution would yield stronger evidence. If the ordered metric information of both kinds of scaling were indeed common, then it could be persuasively argued that the attribute of subjective control is both quantitative and measurable.

To compare the axiomatic and probabilistic scaling solutions it was necessary to perform linear transformations upon both types. It was decided that each kind of scaling solution be transformed linearly onto a 0 – 100 scale. For the Goode’s algorithm solutions derived in Chapter 5, the formula $Y = 100 - \left( 100 \frac{X}{Z} \right)$ where $Z$ was the integer of the greatest magnitude assigned to a statement; and $X$ was the integer assigned to all other statements. This transformation placed the original Goode’s solution onto a new 0 to 100 scale. For the probabilistic scaling solutions, transformations were conducted by initially setting the statement with the largest negative value to zero. The value required to achieve this was then added to each of the remaining statements. Then the statement with the largest positive value was multiplied by a real number such that its new value became 100; and all other statements were then multiplied by this real number. This procedure transformed the original logit scales into 0 to 100 scales.

It was decided that of the probabilistic solutions, the statement location estimates derived from the SHCM for paired comparison data (Andrich & Luo, 1993) and the generalised unfolding model for polytomous responses (Luo, 1998, 2001) would be the
subject of linear transformation. The operation function used with the general model was the hyperbolic cosine and so hence is referred to as the GHCM. This decision was based on the finding in section 6.6.3 of this chapter that the SHCM unfolding model led to stable test – retest statement orders. The GHCM did not lead in some instances to stable test – retest statement orders (Tables 6.3 & 6.10), however, it was decided that the scaling solutions derived from the rating scale data should be investigated.

The new scale values derived from both original scales were then plotted against one-another and graphed for each of the three Subjective Control questionnaires. If the two different theories of unidimensional unfolding (viz., Coombs’s (1964) & Andrich’s (1997)) were enabling estimates of a genuine, interval scalable quantitative attribute, then the plotted points should approximate a perfectly straight line. It would be expected that if they were not measuring such an attribute the plotted points would depart from a straight line. The graphing of the re-scaled solutions did not find either result. It was found that the plots of the re-scaled SHCM statement values formed elegant, curvilinear figures (Appendix 12). As an example, Figure 6.2 depicts the plot for the general version of the Subjective Control scales. The plots of the re-scaled GHCM statement values formed curvilinear figures (Appendix 13), however, these were not as elegant or

![Graph](image)

Figure 6.2. Scatter plot of the transformed Goode’s algorithm and SHCM values for the general version of the Subjective Control Scales.

systematic as those given by the SHCM.

217
These curves suggest that the relationship between the ordered metric information present in the axiomatic and probabilistic solutions is strong and non-linear. Indeed, in the SHCM curves the non-linearity is strikingly systematic and is suggestive of an exponential relationship between the transformed scale values. In the physical sciences non-linear relationships discovered between quantitative variables under experimental conditions are far from unusual (Cheney & Kincaid, 1999; Gerald & Wheatley, 1999). Indeed, one of the most popular families of curvilinear models used in curve estimation of experimental data in the natural sciences is the exponential (Gerald & Wheatley, 1999). So to further explore the non-linear relationship discovered, it was decided to attempt to fit an exponential model of the form $y = e^{(a+bx)}$ to the figures depicted in Appendices 12 & 13.

This was done using the curve-fitting feature of the statistical software program SPSS for Windows, Version 10. The dependent variable in each model was the transformed statement location estimates for each of the Subjective Control scales given by either the SHCM and GHCM unfolding models. The independent variable was the transformed

![General test transformed logit scale](image)

*General test transformed logit scale*

Figure 6.3. Fitting of exponential curve (with constants) to the scatterplot depicted in Figure 6.2. Goode’s algorithm statement locations. Not included in the analyses were the transformed scale values for Statement A given that such values were 0. An exponential model could thus not be fitted given $y = e^x = e^0 = 1 \neq 0$. Consequently, only the values of Statements B to F were used in the curve fitting exercise. The graphs of the curve fitting
exercise for the transformed SHCM values are depicted in Appendix 12a. The graphs of
the curve fitting exercise for the transformed GHCM values are depicted in Appendix
13a. Figure 6.3 depicts the curve fitting exercise for the general version of the Subjective
Control scales.

Table 6.37 displays the results of the exponential curve estimation procedure using the
transformed SHCM statement locations as the dependent variable. The first column
represents the versions of the Subjective Control scales under both test and retest
conditions. The second displays the amount of variance accounted for in the dependent
variable by the model. The last two columns display the values of the model constants $a$
and $b$.

<table>
<thead>
<tr>
<th>Version</th>
<th>$r$-squared</th>
<th>d.f</th>
<th>F</th>
<th>$a$</th>
<th>$b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>.983</td>
<td>3</td>
<td>177.09**</td>
<td>5.34</td>
<td>.029</td>
</tr>
<tr>
<td>General (retest)</td>
<td>.989</td>
<td>3</td>
<td>274.48**</td>
<td>5.19</td>
<td>.029</td>
</tr>
<tr>
<td>Impulses</td>
<td>.989</td>
<td>3</td>
<td>282.14**</td>
<td>16.06</td>
<td>.018</td>
</tr>
<tr>
<td>Impulses (retest)</td>
<td>.987</td>
<td>3</td>
<td>222.07**</td>
<td>12.70</td>
<td>.020</td>
</tr>
<tr>
<td>Time In.</td>
<td>.954</td>
<td>3</td>
<td>62.14**</td>
<td>10.34</td>
<td>.021</td>
</tr>
<tr>
<td>Time In. (retest)</td>
<td>.986</td>
<td>3</td>
<td>208.68**</td>
<td>12.98</td>
<td>.020</td>
</tr>
<tr>
<td>Time In.</td>
<td>.951</td>
<td>3</td>
<td>58.03**</td>
<td>3.10</td>
<td>.033</td>
</tr>
<tr>
<td>Time In. (retest)</td>
<td>.992</td>
<td>3</td>
<td>361.26**</td>
<td>4.01</td>
<td>.031</td>
</tr>
</tbody>
</table>

** $p < .01$

The fit of the exponential model to the transformed SHCM statement locations was
excellent across all three versions of the Subjective Control scales (Table 6.37 &
Appendix 12a). The amount of variance accounted for in the dependent variable by the
exponential models exceeded 90% and in some instances was approximately 99%. This
strongly suggests that an exponential function exists between the Goode’s algorithm
scaling solution and the SHCM scaling solutions.

Table 6.38 displays the results of the exponential curve estimation procedure using the
transformed GHCM statement locations as the dependent variable. The first column
represents the versions of the Subjective Control scales under both test and retest
conditions. The last two rows display an additional two models for the time involvement
version. This was done because either of the Goode’s algorithm solutions could be used
with this version. The last two rows are models estimated using the Goode’s solution
depicted in Chapter 5, Figure 5.19. The second column displays the amount of variance
accounted for in the dependent variable by the model. The last two columns display the
values of the model constants $a$ and $b$. 

219
The fit of the exponential model to the transformed GHCM statement locations ranged from satisfactory to very poor across all three versions of the Subjective Control scales (Table 6.38 & Appendix 13a). Variance in the dependent variable accounted for by the exponential models ranged from 72% to 96%. Moreover, the F ratios displayed in the fourth column varied in magnitude and in levels of statistical significance. These results, however, were supportive of the results found in the curve estimation performed with the transformed SHCM values.

<table>
<thead>
<tr>
<th>Version</th>
<th>r-squared</th>
<th>d.f</th>
<th>F</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>.758</td>
<td>3</td>
<td>9.37*</td>
<td>4.02</td>
<td>.029</td>
</tr>
<tr>
<td>General (retest)</td>
<td>.909</td>
<td>3</td>
<td>30.11*</td>
<td>3.49</td>
<td>.031</td>
</tr>
<tr>
<td>Impulses</td>
<td>.933</td>
<td>3</td>
<td>42.05**</td>
<td>11.20</td>
<td>.020</td>
</tr>
<tr>
<td>Impulses (retest)</td>
<td>.921</td>
<td>3</td>
<td>34.97**</td>
<td>10.75</td>
<td>.020</td>
</tr>
<tr>
<td>Time In</td>
<td>.960</td>
<td>3</td>
<td>72.47**</td>
<td>5.55</td>
<td>.030</td>
</tr>
<tr>
<td>Time In (retest)</td>
<td>.794</td>
<td>3</td>
<td>11.56*</td>
<td>7.86</td>
<td>.022</td>
</tr>
<tr>
<td>Time In</td>
<td>.929</td>
<td>3</td>
<td>39.11**</td>
<td>1.20</td>
<td>.042</td>
</tr>
<tr>
<td>Time In (retest)</td>
<td>.716</td>
<td>3</td>
<td>7.55</td>
<td>2.51</td>
<td>.033</td>
</tr>
</tbody>
</table>

*p < .05  **p < .01

In the natural sciences, non-linear relations are often difficult to solve and quite often the natural logarithm of the dependent and/or independent variables is taken to linearise the relationship (Gerald & Wheatley, 1999). Hence, as a further test of the exponential relationship between the axiomatic and probabilistic scaling solutions, it was decided that the natural logarithm of the transformed probabilistic solutions be calculated. If the relationship between the two kinds of scaling solution was indeed exponential, then plotting the natural logarithms of the transformed probabilistic solution against the transformed Goode’s algorithm solution should produce a figure that approximates a straight line. To this end, the natural logarithms of the transformed SHCM statement locations were calculated.

Appendix 12b displays the results for all three versions of the Subjective Control scales of fitting a linear model to the natural logarithms of the transformed SHCM solution against the Goode’s algorithm solution. Table 6.39 displays the model statistics. It was found that the linear models fitted the data excellently. This finding strongly suggested that an exponential relationship exists between the axiomatic and probabilistic scaling solutions.
Table 6.39: Linear model statistics with the log transformed SHCM values as the dependent variable.

<table>
<thead>
<tr>
<th>Version</th>
<th>r-squared</th>
<th>d.f</th>
<th>F</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>.983</td>
<td>3</td>
<td>177.09**</td>
<td>1.68</td>
<td>.029</td>
</tr>
<tr>
<td>General (retest)</td>
<td>.989</td>
<td>3</td>
<td>274.48**</td>
<td>1.65</td>
<td>.029</td>
</tr>
<tr>
<td>Impulses</td>
<td>.989</td>
<td>3</td>
<td>282.14**</td>
<td>2.78</td>
<td>.018</td>
</tr>
<tr>
<td>Impulses (retest)</td>
<td>.987</td>
<td>3</td>
<td>222.07**</td>
<td>2.54</td>
<td>.020</td>
</tr>
<tr>
<td>Time In.</td>
<td>.954</td>
<td>3</td>
<td>62.14**</td>
<td>2.34</td>
<td>.021</td>
</tr>
<tr>
<td>Time In. (retest)</td>
<td>.986</td>
<td>3</td>
<td>208.68**</td>
<td>2.56</td>
<td>.020</td>
</tr>
<tr>
<td>Time In.</td>
<td>.951</td>
<td>3</td>
<td>58.03**</td>
<td>1.12</td>
<td>.033</td>
</tr>
<tr>
<td>Time In. (retest)</td>
<td>.992</td>
<td>3</td>
<td>361.26**</td>
<td>1.39</td>
<td>.031</td>
</tr>
</tbody>
</table>

** p < .01

The natural logarithms of the transformed GHCM statement locations were also calculated. Appendix 13b displays the results for all three versions of the Subjective Control scales of fitting a linear model to the natural logarithms of the transformed SHCM solution against the Goodes’ algorithm solution. Table 6.40 displays the model statistics.

Table 6.40: Linear model statistics with the log transformed GHCM values as the dependent variable.

<table>
<thead>
<tr>
<th>Version</th>
<th>r-squared</th>
<th>d.f</th>
<th>F</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>.758</td>
<td>3</td>
<td>9.37</td>
<td>1.39</td>
<td>.029</td>
</tr>
<tr>
<td>General (retest)</td>
<td>.909</td>
<td>3</td>
<td>30.11*</td>
<td>1.25</td>
<td>.031</td>
</tr>
<tr>
<td>Impulses</td>
<td>.933</td>
<td>3</td>
<td>42.05**</td>
<td>2.42</td>
<td>.020</td>
</tr>
<tr>
<td>Impulses (retest)</td>
<td>.921</td>
<td>3</td>
<td>34.97**</td>
<td>2.38</td>
<td>.020</td>
</tr>
<tr>
<td>Time In.</td>
<td>.960</td>
<td>3</td>
<td>72.47**</td>
<td>1.71</td>
<td>.027</td>
</tr>
<tr>
<td>Time In. (retest)</td>
<td>.794</td>
<td>3</td>
<td>11.56*</td>
<td>2.06</td>
<td>.022</td>
</tr>
<tr>
<td>Time In.</td>
<td>.929</td>
<td>3</td>
<td>39.11**</td>
<td>.181</td>
<td>.042</td>
</tr>
<tr>
<td>Time In. (retest)</td>
<td>.716</td>
<td>3</td>
<td>7.55</td>
<td>.918</td>
<td>.033</td>
</tr>
</tbody>
</table>

* p < .05 ** p < .01

It was found that the fit of the linear models to the data ranged from satisfactory to very poor. Despite the relatively poor fit of these linear models, the results were supportive of the results found with the SHCM scaling solutions for each of the Subjective Control scales.

6.8 Discussion and conclusions

The aim of the present study was fourfold. The first was to test three members of the family of probabilistic unfolding functions on the rating scale data obtained using the procedures outlined in Chapter 5. The second was to test the SHCM unfolding model for pairwise preferences (Andrich & Luo, 1993) using the raw paired comparison data. The
third was to compare the obtained probabilistic solutions between the test and retest phases of data collection for both types of collected data. The fourth was to compare the scaling solutions of the SHCM & GHCM probabilistic models against the Goode's minimum integer solutions of the Coomb's (1964) analysis of Chapter 5.

The comparison of the probabilistic and axiomatic scaling solutions of the Subjective Control scales produced the most striking finding of the present study. This was the discovery of the exponential relationship between the SHCM and Goode's algorithm scaling solutions. It is to the best knowledge of the researcher that such a relationship has hitherto not been found between Coombs (1964) deterministic theory of unfolding and the various probabilistic unfolding models proposed thus far. The highly systematic nature of the non-linear relationship between the scaling solutions of two different theories of unidimensional unfolding (viz., Coombs (1964) and Andrich, (1989b)) could be possibly indicative of something very important. This deserves detailed discussion.

Chapter 1 argued that measurement is the estimation of the ratio between a continuous magnitude and a unit magnitude of the same kind. A ratio was argued to instantiate a real number. It is not sufficient, however, to define ratios (and thus the real numbers) simply as binary relations between magnitudes of continuous quantities. In actuality, a ratio is a ternary relation. That is, measurement is the estimation of the ratio between a continuous magnitude and a unit magnitude of the same kind, relative to the conception of additivity employed (Michell, 1993, 1994b).

This is exemplified in physics with the continuous quantity of velocity. As outlined in Chapter 1, Newton argued that the velocity was an extensive quantity open to the operation of concatenation. For example, a person is walking along a corridor in a moving train that was travelling due north. According to Newton, the velocity of the person relative to the ground could be estimated by simply concatenating the velocity of the person relative to the train with the velocity of the train relative to the ground. Algebraically, this example takes the form $v_{pg} = v_{pt} + v_{tg}$. Einstein, however, argued that velocities could not be concatenated as velocity possessed an upper bound. This upper bound was the speed of light $c$. Using Einstein’s formula, the velocity of the person relative to the ground would be calculated thus: $v_{pg} = (v_{pt} + v_{tg})(1 + v_{pt}v_{tg}c^{-2})^{-1}$.

It is not well known outside of physics that Einstein’s velocities can be concatenated as argued by Newton. Using the above example, if the unit of velocity is that of light, then let $v_{pg} = z$, $v_{pt} = x$ and $v_{tg} = y$. Then $f(z) = f(x) + f(y)$ iff
\[ f(a) = \tanh^{-1}(a) = \frac{1}{2} \ln\left(\frac{1+a}{1-a}\right), \]
where \( \tanh^{-1} \) is the inverse hyperbolic tangent function (Krantz, et al, 1971; Michell, 1990). It must be stressed that neither Newton’s or Einstein’s theories are incorrect. They both are correct. The important thing that must be noted is that the difference in their values (aside from any measurement error) lies in the fact that both are measurements made relative to different conceptions of additivity. Velocity can be measured using different conceptions of additivity because it is an attribute whose automorphisms are 1 point homogeneous and form Archimedean ordered mathematical groups (Luce, 1987, 2001).

The curve estimation procedure discovered evidence to suggest that a continuous mathematical function may hold between the statement locations given by Coombs’s (1964) theory of unidimensional unfolding and the probabilistic simple hyperbolic cosine model (SHCM) of unfolding (Andrich, 1988b, 1989). The pertinent mathematical function was the exponential \( y = e^x \) or \( y = \exp(x) \). The curve estimation procedure conducted on the statement locations given by Coombs’s (1964) and the general hyperbolic cosine model (GHCM) (Luo, 1998, 2001) yielded weaker evidence of an exponential function relating the two kinds of scaling solutions. Nevertheless, both curve estimation procedures produced empirical evidence consistent with the hypothesis that the different theories of unfolding hold different conceptions of the additivity of the psychological attribute of subjective control.

If Andrich’s (1988b, 1989) and Coombs’s (1964) theories of unfolding do conceptualise the additivity of latent psychological attributes differently, it must be consequential of their being different theories of preferential choice behaviour. This difference may lie in the different arguments made of the underlying response process. Coombs (1950, 1964) argues that responses to stimuli ordered upon one relevant dimension are governed by a deterministic single peaked preference function (Coombs & Avrunin, 1977). The order of the stimuli along the dimension is inferred at the manifest (Andrich, 1996) level of the \( I \) scales. The \( I \) scales, made by participants who ostensibly folded the qualitative \( J \) scale at their point of maximum preference, are unfolded to ascertain the nature the ordered metric \( J \) scale. Symmetric and single peaked preference functions which decrease monotonically from the point of maximum preference are inferred at the manifest level by the presence of a set of transitive \( I \) scales.

The SHCM (Andrich, 1988b, 1989; Andrich & Luo, 1993) and the GHCM (Luo, 1998, 2001) both argue of the presence of a symmetric and decreasing monotonic preference
function in preferential choice behaviour. They argue, however, that the preference response process operates at the latent rather than manifest level (Andrich, 1996). Andrich (1995, 1996) characterised the preference response process in the SHCM as consisting of three latent, cumulative responses. He argued that a respondent may disagree with a statement for two reasons. The person may disagree because the statement may be below the person’s location upon the continuum. Andrich called this latent cumulative response Disagree Below. The person may also disagree with a statement because that statement is above the person’s location upon the continuum. Andrich called this latent cumulative response Disagree Above. The third latent response process was Agree Close, where a statement was very near the person’s location upon the continuum. Andrich (1995, 1996) argued that the two latent and cumulative Disagree Above and Disagree Below responses could be summed or folded to obtain the single trough, manifest Disagree response. That is, for comparisons involving pairs of statements, the probability of the person’s actual disagreement with one statement within each pair can be obtained by summing the latent disagree responses. Andrich (1996, pp. 352-353) succinctly contrasted his SHCM with the deterministic work of Coombs (1964):

In the traditional [Coombs] approach, the focus is on the Agree/Disagree response [to paired comparisons], recognising that the Disagree response gives no information about direction, and the aim is to unfold the responses to give the two directions. In the present approach, an unfolded model is applied to the latent responses made explicit in which a direction is implied immediately, but the two response curves which characterise the directions of the Disagree response must be folded to correspond to the data.

The results of present study suggest that the SHCM of Andrich (1988a, 1989, 1997) and Coombs’s (1964) theory of unidimensional unfolding are indeed two theoretically different ways of conceptualising preferential choice behaviour. That the scaling solutions of the SHCM and Coombs theory are related by a continuous mathematical function suggests that they conceptualise the single peaked preference function in a manner analogous to how Newton’s and Einstein’s theories conceptualised velocity. Thus from the two different ways of conceptualising preference behaviour flows different conceptions of the additivity of the latent, psychological attribute in question.

If Coombs’s theory and the SHCM are indeed different theoretical conceptions of the single peaked preference function, then both theories enable the measurement of psychological attributes. Both theories, however, argue that measurements of such attributes are unique up to affine (linear) transformations only. That is, the measurements
are located upon an interval scale. The attribute of subjective control, however, may actually possess a more complex form of quantitative structure. It may actually be quantitative at the ratio scale level given that the discovered exponential relationship between the two scaling solutions is consistent with the arguments presented by Luce (1987, 2001) of the Archimedean ordered group. If the structure of the attribute of subjective control is complex enough to support homogeneous and Archimedean ordered groups of translations, then it logically follows that it is complex enough to be measured at the ratio scale level (Luce, 1987, 2001). Although Coombs theory and the SHCM are limited to providing measures of psychological attributes up to linear transformations only, the results of the present study have enabled the plausible theoretical possibility of ratio scale measurement of the attribute of subjective control. Future research, however, would have to be conducted to ascertain this.

The results of the curve estimation procedures, however, were limited in empirical scope. Both theories of unfolding measured the locations of only six statements given the fact that the ordinal determinables used in the construction of the Subjective Control scales produced this number of statements. Thus the number of data points plotted in the curve estimation procedure was quite small. Hence on this basis, it was possible that the curvilinear relationships discovered were not exponential but were of some other kind of functional form. A strong suggestion for future research would be an attempt to replicate the findings of the curve estimations undertaken in this thesis. Such a replication study should involve the construction of more than six statements. Eight statements would increase the empirical scope of the study by not only providing a greater number of measurements of the attribute of interest, but by also enabling a more stringent test of additivity than that of double cancellation (viz., triple cancellation or the Reidermeister condition (Krantz, et al, 1971)). A future study employing these suggestions would be in a far stronger empirical position than the present study.

The other aims of the present study will now be discussed. In regards to the first aim, the present study was somewhat limited by the available computer software in that only the rating scale data could be examined using more than one probabilistic unfolding function. Tables 6.1 to 6.14 display the results of such analyses. The simple square or PARELLA function was by far the worst fitting member of the family of probabilistic unfolding functions. The fit of the PARELLA unfolding model was indeed so poor that the RATEfold computer software could not compute a PARELLA model for the time involvement and impulses to gamble versions of the Subjective Control scales. Only the
data from the general version of the Subjective Control scales enabled a PARELLA model to be estimated.

Tables 6.5 and 6.6 display the results of these analyses. The PARELLA model did not retrieve the ordinal information concerning the statements. Both in the test and retest phases, the most appropriate form of data fit to the PARELLA model was the statement order BACFED. This was a significant departure from the ABCDEF ordering predicted by the ordinal determinable used construct the statements. It also runs contrary to the findings of the axiomatic analyses conducted in Chapter 5. Thus any consistency in the ordered metric information between the axiomatic model and the PARELLA model is automatically destroyed. Interestingly, for the test phase the best fitting PARELLA model was with the statements possessing the same, fixed latitude of acceptance parameter (Table 6.5). In the retest phase, the best fitting PARELLA model estimated different latitudes of acceptance (Table 6.6). This perhaps suggests that the properties of the statements changed considerably from test to retest phases; thus suggesting that the test – retest reliability of the questionnaire was poor. This, however, runs counter to the findings of axiomatic analyses of Chapter 5.

Figures 25 – 36 in Appendix 4 demonstrate the fit of the PARELLA model to the data graphically. It can be seen that there was a tendency for the data to fit the theoretical curves better in the retest phase than in the test phase, suggesting that the statements did indeed have differing latitudes of acceptance. Statements A, E and F displayed quite reasonable fit the PARELLA model, however, Statement B displayed extremely poor fit. Perhaps why the PARELLA model demonstrated such a poor fit to the data was due to the exacting demands the function places upon data as unstructured as rating scale data. The PARELLA model predicts that as a person’s ideal point of preference becomes closer to the statement, the probability of that person agreeing to the statement increases sharply, to the extent that if the person’s point of maximum preference (the person’s location) is exactly the same as the statement, then the probability of the person choosing that statement is exactly 1. This could be too much of a demand to make upon raw rating scale data with the propensity of such data to have tied ratings between greatly differing statements. Perhaps the PARELLA model may have demonstrated a better fit to the data if the data had been the raw paired comparison data. This data generally displays more structure than does rating scale data. Such testing, however, will have to await further theoretical developments and the extension and development of current computer software.
Nevertheless, the person location estimates produced by the PARELLA unfolding model for the general version of the Subjective Control Scales did correlate moderately and significantly with the key criterion variables of frequency of gambling play and within session expenditure (Table 6.15). This suggests that despite the bad fit of the data the PARELLA function did produce an unfolding model with some criterion validity. The PARELLA model person location estimates also correlated negatively, moderately and significantly with both the 12 and 18 item versions of the Scale of Gambling Choices (SGC) (Baron, Dickerson & Blaszczynski, 1995). This suggests that the PARELLA model also displayed some concurrent validity. Hence despite its limitations, the PARELLA model did retrieve some psychometric information from the rating scale data.

The simple squared logistic function (SSLM) and the hyperbolic cosine function (HCM) produced models that were a much better fit to the data than the square PARELLA model. Unlike the latter function, the SSLM and the HCM functions do not require the peak of the curve to represent a probability of one of responding to that item; and so hence are more suited to raw data with less structure. Unlike the PARELLA function, the RATEfold computer program was able to estimate probabilistic unfolding models using both the SSLM and HCM for each of the three Subjective Control scales.

For the general version of the Subjective Control Scales, the SSLM and HCM functions produced unfolding models in the test phase that did not retrieve the ordering of the statements as predicted by the ordinal determinable. With the SSLM, statements D and C received the same item location estimate; whilst the HCM produced the statement ordering of ABDCEF. An initial explanation may be posited that these particular statements were poor fits to the models. Inspection of the item expectation curves for these statements (Appendix 4, Figures 5 – 8 and 17 – 20), however, found that these items were an excellent fit to the models. Indeed, statements A and B displayed less fit to the theoretical expected value curves than did statements C and D. In the retest phase, however, both the SSLM and the HCM unfolding models in the retest phase produced the expected statement ordering of ABCDEF. Inspection of the relevant figures in Appendix 4 indicated that the retest phase data tended generally to be a better fit to the theoretical curves than the test phase data. Unfortunately, this may reflect that there was a strong learning effect which carried over from the test phase despite the administration of the two versions of the SGC as a filler task. Participants' completion of the more exacting paired comparison and ranking tasks in the test phase may have induced more structure in their responses to the rating scale task in the retest phase.
Both the SSSLM and the HCM unfolding models produced person location estimates that correlated negatively, moderately and significantly with the key criterion variables of frequency of play and within session expenditure (Table 6.15). Additionally, the magnitude of these correlations was greater than those produced by the person location estimates of the PARELLA model. The SSSLM and HCM models also produced negative, high and significant correlations between the estimated person locations and the total scores of both the 12 and 18 item versions of the SGC (Table 6.15). These findings suggest that the HCM and SSSLM functions were able to produce probabilistic unfolding models which displayed sound criterion and concurrent validity.

The SSSLM and the HCM unfolding models for the time involvement version of the Subjective Control Scales produced ambiguous results. The SSSLM retrieved from the rating scale data in the test phase the statement order predicted by the ordinal determinable. In the retest phase, however, the order ABCEDF was produced. Exactly the same statement orders were produced by the HCM unfolding models in both the test and retest phases. These findings suggest two conclusions. Firstly, they cast doubt upon there being a strong learning effect between the test and retest phases of questionnaire administration as suggested earlier. Secondly, that the models themselves suffered a lack of test-retest reliability. The first conclusion is speculative and the second contravenes the axiomatic model findings of Chapter 5. Therefore, these ambiguous results make interpretation of the SSSLM and HCM models for the time involvement questionnaire problematic.

Nevertheless, both the SSSLM and the HCM unfolding models produced person location estimates that correlated negatively, moderately and significantly with the key criterion variables of frequency of play and within session expenditure (Table 6.16). The SSSLM and HCM models also produced negative, high and significant correlations between the estimated person locations and the total scores of both the 12 and 18 item versions of the SGC (Table 6.16). These latter correlations, however, were slightly larger in the retest phase than in the test phase. The findings suggest that the HCM and SSSLM functions were able to produce probabilistic unfolding models which displayed sound criterion and concurrent validity.

The SSSLM and HCM unfolding models for the impulses to gamble version of the Subjective Control scales produced results that were different again. The SSSLM model retrieved from the rating scale data, in both the test and retest phases, the statement order as predicted by the ordinal determinable. The HCM model, however, produced in the test
phase the statement order ABDCEF. In the retest phase, the model retrieved the statement order predicted by ordinal determinable. Perhaps in this case the square logistic function leads to a model which better explains participants’ responses to this particular questionnaire.

Both the SSLM and the HCM unfolding models produced person location estimates that correlated negatively, moderately and significantly with the key criterion variables of frequency of play and within session expenditure (Table 6.17). The SSLM and HCM models also produced negative, high and significant correlations between the estimated person locations and the total scores of both the 12 and 18 item versions of the SGC (Table 6.17). These findings suggest that the HCM and SSLM functions were able to produce probabilistic unfolding models which displayed sound criterion and concurrent validity.

The SHCM models for pairwise preferences (Andrich, 1988a, 1989) delivered scaling results much stronger than any of the models used on the rating scale data. These results were different to those found for the unilateral paired comparison data of the third pilot study (Appendix 3). In that study the statement order was CBADEF for all three versions of the Subjective Control scales with the data fitting the model well. This discrepancy in statement orders between the present study and the final pilot study could be due to the different participant samples employed. The latter study’s sample consisted entirely of first year university students and therefore was unrealistic as a sample of genuine gamblers.

For the general version of the Subjective Control scales, the SHCM ordered the statements as predicted by the ordinal determinable (Table 6.30). This order was confirmed in the retest phase of test administration. As a check on test-retest reliability, the statement location estimates discovered in the retest phase were compared with each of the corresponding estimates discovered in the test phase. The purpose of the comparison was to see if the former estimates were within one standard error of the latter estimates. This was the case for all statements except statement B. This suggests that the paired comparison data gathered for this questionnaire was much more structured than the rating scale data.

The chi – square tests of model fit (Table 6.31) suggested that the overall fit of the model to the data was good with the exception of statements A and B. The paired comparison tasks among statements A, B and C and among C, D, E and F fitted the HCM model quite well. Statements A and B, however, when compared with statements D, E
and F, produced chi-squares of large magnitude and statistical significance. The item characteristic curves (ICCs) for these comparisons (Appendix 8) were inspected. It was discovered that the pairwise preference behaviour of the participant group with a negative mean location estimate was unusual. This group tended to respond more favourably towards A and B as paired comparisons progressed from statements D to F. Inspection of Figs. 5, 7 and 9 of Appendix 8 revealed that the probabilities of responding favourably to statement A when compared against statements D, E and F were approximately .2, .35 and .5, respectively. This is indeed highly unusual behaviour. The majority of the participants in this group were self-referred problem gamblers who were administered the questionnaires by their counsellors and not the researcher. Hence the most plausible explanation is that these participants were perhaps confused by the bilateral paired comparison tasks and did not have the direct assistance of the researcher in completing them.

Similar findings were discovered with the time involvement version of the Subjective Control scales. The SHCM unfolding (Andrich, 1988a, 1989) ordered the statements as predicted by the ordinal determinable both in the test and retest phases (Table 6.32). Unlike those for the the general version of the Subjective Control scales, only the retest location of statement D was within one standard error of the test location. As for the general version, a similar pattern of misfit emerged between statement A and statements D, E and F and statement B and statements D and E (Table 6.33). Inspection of the pertinent ICCs in Appendix 9 discovered that the participant group with the mean negative location again tended to respond more favourably towards A and B as paired comparisons progressed from statements D to F. Inspection of Figs. 5, 7 and 9 of Appendix 9 revealed that the probabilities of responding favourably to statement A when compared against statements D, E and F were approximately .25, .25 and .4, respectively. Like the general version, this unusual behaviour led to the misfit of these comparisons to the model.

Again, a very similar pattern of responses occurred to the impulses to gamble version of the Subjective Control scales. The statement orders were as predicted by the ordinal determinable both in the test and retest phases of test administration (Table 6.34). Similar patterns of paired comparison model misfit occurred between statement A and statements D, E and F and statement B and statements E and F (Table 6.35). Inspection of Figs. 5, 7 and 9 of Appendix 10 revealed that the probabilities of responding favourably to statement A when compared against statements D, E and F were approximately .15, .32
and .4, respectively. Like the other versions, this unusual behaviour led to the misfit of these comparisons to the model.

Despite the unusual pair comparison behaviour discovered, the HCM unfolding model did provide scaling solutions which exhibited sound criterion and concurrent validity (Table 6.36). Very similarly for the rating scale unfolding models, the correlations between the criterion variables and the person location estimates were moderate, negative and statistically significant. Like the rating scale models, the correlations between the 12 and 18 item versions of the SGC were strong, negative and statistically significant. That these findings are very similar to those of the rating scale models suggest that the Subjective Control scales exhibit moderate criterion validity and strong concurrent validity. This in turn supports the axiomatic findings of Chapter 5.

Strong discriminative validity for all versions of the Subjective Control scales was demonstrated by both the rating scale SSLM and HCM unfolding models (Tables 6.18 – 6.29). The one way ANOVA and post – hoc comparison tests performed upon the person location estimates found that the mean person locations for each of the three participant groups were significantly different. For all three questionnaires, the mean person location for the student group was significantly greater than both the in situ club and self-referred problem gambler groups, with the mean person location of the in situ club group being significantly higher than that of the self – referred problem group. This pattern was also supported in the retest phase. This suggests that all three versions of the Subjective Control scales can discriminate strongly between these three different groups of gamblers using only rating scale data. Thus it is possible that the Subjective Control scales can be of immediate utility in clinical applications where sound discrimination between criterion groups of gamblers is required.

Sound internal reliability estimates (PSIs) were also calculated by the rating scale models; suggesting that the Subjective Control scales were sufficiently internally reliable. The total and participant group PSIs were greater across all three versions using the HCM unfolding models than the SSLM ones. This suggests that the HCM unfolding model may generate scaling solutions that are more reliable for rating scale data than the SSLM. The PSIs for the self – referred problem group were consistently lower than the other two participant groups across all three versions. This finding supports the axiomatic findings of the previous chapter in that the data from this group were more erroneous than those from the other groups.
An exception to the pattern of findings were the very poor PSIs calculated by both models for the general version in the test phase. This finding can possibly be interpreted as a consequence of questionnaire presentation and design. The first set of tasks completed in the test phase by all participants was the rating scale set for the general version. Participants may have been unsure about how to respond to the statements. This may indicate a problem with the initial instructions given to participants.

The better scaling solutions yielded by the SHCM unfolding models (Andrich, 1988b, 1989) suggest that paired comparison data is more structured than rating scale data. The aforementioned propensity of rating scales to elicit tied responses from participants may be limiting the scaling information available from the participant sample. It would thus be wise for future research to incorporate a section for paired comparison tasks in any questionnaire attempting to measure preferences primarily through rating scale tasks.

Nevertheless, across all three versions of the Subjective Control scales the results of the rating scale unfolding models were consistent with the arguments presented by Andrich (1996). Andrich argued that responses to Likert (1932) style rating scales could actually be governed by a single peaked preference function, despite the ostensibly cumulative design of the rating scale. That the rating scale unfolding models lead in most cases to the unidimensional statement orders predicted by the ordinal determinable (Michell, 1998) suggests that a single peaked preference function possibly governed responses made to the ratings tasks of the present study. Moreover, the transformed statement location values derived from the rating scale GHCM unfolding model (Luo, 1998, 2001) also displayed curvilinear relationships with the transformed Goode’s algorithm values (Appendices 13, 13a, 13b). These curves, however, were not as elegant as those found with the SHCM transformed statement locations, suggesting that tied responses from participants might have obfuscated the true nature of the curvilinear relationships.

The findings of all the probabilistic analyses conducted in this chapter lead to several different conclusions. One of the most pertinent is that IRT theories of unidimensional unfolding are tractable models that can be used in the development of psychometric apparatus. The investigations of the present study found that data fitted to such IRT models demonstrated raw data that possessed too much error to satisfy a deterministic, axiomatic model. This was especially so with the rating scale data. This is not to say, however, that the IRT models are in any way conceptually superior to Coombs’s (1964) determinist model or axiomatic conjoint measurement (Luce & Tukey, 1964). The primary advantage is of practical utility. The IRT models demand less in terms of
structure in data and thus data collection can made relatively easy by the use of rating scales. A primary research niche the unfolding models for rating scale data (Luo, 2001) could then occupy would be in the pilot testing of pertinent psychometric apparatus devised according to unidimensional unfolding theory. Thus both deterministic and IRT models could be used in a complementary manner in psychometric scale construction.

Another conclusion that can be wrought from the findings of the present chapter is a substantive one. Like the axiomatic results of the previous chapter, the results generated by the IRT models of unfolding suggest that subjective control over gambling can be conceptualised as a unidimensional psychological property of necessary conscious deliberation upon engagement in gambling behaviour. This suggests that the dispositional arguments presented thus far of subjective control (such as Baron et al, 1995 and Edwards, 1986) are not necessary for either fruitful conceptualisation or successful (tentative) measurement. The results of this chapter and the previous one strongly suggest that real, in situ club EGM gamblers, self-referred problem gamblers and infrequent student gamblers can all be located along the same continuum of subjective control over gambling. The location of such criterion groups along a single, relevant psychological continuum has traditionally been the goal of alcoholism research (Edwards, 1986; Edwards & Gross, 1976) and gambling research (Dickerson & Baron, 2000; Dickerson, 1991; Shepherd & Dickerson, 2001). This goal has been effectively (albeit tentatively) achieved in the present study using quantitative theories of psychology quite different (and more conceptually sophisticated) than the traditional method of factor analysis.

But perhaps the strongest conclusion pertains not to the measurement of the statements of the Subjective Control scales, but to the manner in which the statements themselves were constructed. Both axiomatically in the previous chapter and probabilistically in the current one, Michell’s (1994, 1998) theory of the ordinal determinable was highly successful in creating statements of which scaling solutions could be derived. The statement order in the data when Coombs’s (1964) theory and the IRT models were used matched the statement order as hypothesised by Michell’s theory. This suggests that perhaps the strongest influence over the ordered metric information of both the axiomatic and probabilistic scaling solutions lies in the pattern of ostensibly non-quantitative logical relations holding between the written statement predicates on the basis of their obvious semantic content. Perhaps then the strength of the findings of the current and previous chapters does not lie in the conceptual strength of the mathematical models employed in data analysis, but in the non-quantitative method of stimulus construction.
and control. It is possible that quantitative effects like those found in the present study can be generated by the behaviour of non-quantitative structures (Michell, 1999). In the light of the present findings, Michell’s theory of the ordinal determinable is deserving of further serious research attention both from psychometricians and mathematical psychologists interested in constructing statements for use in written psychological tests.
Chapter Seven: Final discussions and conclusions

This thesis sought to test empirically an assumption of quantitative structure with respect to the attribute of subjective control. The investigation of this attribute was conducted within the substantive area of gambling behaviour. In order for such investigation to proceed it was necessary to redefine subjective control as the degree of conscious inhibition required over the engagement of the self in the behaviours Orford (1985, 2000) termed appetitive. Behaviours that Orford identified as appetitive included smoking, drinking alcohol, narcotics, gambling and sexual activity.

This new definition did indeed provide a fruitful substantive basis for an investigation into some theories of psychological measurement. Using this definition as a basis for scale construction, it was found that the ratings, rank orders and paired comparisons elicited by study participants lead to the satisfaction of the conditions of Coombs’s (1964) theory of unidimensional unfolding. This was an impressive achievement in its own right. Given the demands that the unfolding and dominant path conditions make of respondents’ data, Coombs’s theory does not automatically guarantee the investigator a scaling solution. Intransitive paired comparisons and rank orders will readily confound these conditions if there are a sufficient number of them present in a set of empirical data. Controlling these confounding sources of error requires intensive research into methods of experimental control, especially stimulus control. Achieving such methodology, however, is no mean feat. As Michell (1990) opined, it is a direct consequence of its stringent requirements that psychologists have ignored Coombs’s theory in favour of other methods that will always result in a scaling solution regardless of the structure present within data, such as Likert’s (1932) theory of ratings. The present study has demonstrated that the rigourous requirements of Coombs’s (1964) theory need not be insurmountable and in fact the theory can be employed successfully.

It must be noted that this success was achieved without resort to the doctrine of operationism (Stevens, 1946, 1951). Operationism was the subject of detailed, critical discussion in the second chapter of this thesis. There it was argued the discipline of psychology as a whole mistakenly argues that operational definitions of attributes must be constructed before any attempt at the measurement of those attributes is made. The survey of texts in psychological measurement yielded strong evidence in support of this argument; in that virtually all of the texts advocated the operational theory of measurement (Stevens, 1946, 1951).
The definition of subjective control advanced in Chapter 4, however, was not of an operational nature and therefore went against the conventional wisdom of psychology. Nonetheless it enabled an interval level scaling solution to be derived from a deterministic theory of unfolding (viz., Coombs, 1964). Moreover, this derived scaling solution contained ordered metric information different from that predicted by the theory of the ordinal determinable (Michell, 1994a, 1998). If it had been argued that the statements contained in the Subjective Control scales comprised an operational definition of subjective control, this particular finding would have necessarily lead to the conclusion that this operational definition was incorrect; and thus an entirely new set of scales would have had to have been created. In a rather different interpretation, the present study argued in Chapter 5 that the difference between the predicted and discovered ordered metric information was possibly resultant of predicate specificity (Michell, 1998). At the initial research stage this is almost unavoidable and the only way of addressing the problem of predicate specificity is by future intensive research into the predicates relating to subjective control. It is a plausible possibility that such research may discover predicates that result in empirical ordered metric information that is consistent with that predicted by the ordinal determinable. Thus the problem of differing ordered metric information is one of stimulus control and not of the theoretical definition of the attribute concerned.

In essence, one conclusion can be drawn from the results of the present study with regards to the doctrine of operationism. Contrary to the conventional wisdom of psychology, it is not at all necessary to construct operational definitions of psychological attributes prior to their attempted measurement. Such definitions are simply unproductive conceptual ‘baggage’ which may actually interfere with the understanding of these attributes; as operationism necessarily confuses any attribute or property with the methods used to observe it.

A very impressive finding was that the ordered metric information contained in the Coombs’s scaling solutions satisfied the axioms of conjoint measurement (Luce & Tukey, 1964). Three interpretations can be made of this. Firstly, the finding adds further support to the argument that operationism is not required in the measurement of psychological attributes. Secondly, it is evidence consistent with the argument that Coombs’s (1964) theory of unidimensional unfolding is a genuine method of psychological measurement. That is, it can provide genuine measures of persons and stimuli that are unique up to affine transformations. Thirdly, it is tentative evidence in
support of subjective control being a genuinely quantitative attribute similar to those found in the physical sciences, like temperature for example. To the best knowledge of the author, this thesis constitutes the first application of Coombs’s (1964) theory and axiomatic conjoint measurement (Luce & Tukey, 1964) to a psychological attribute in the substantive field of addictive behaviours.

The success of axiomatic conjoint measurement (Luce & Tukey, 1964) in the present study also provides some perspective on the issues raised by Cliff (1992) and Narens & Luce (1993). The present study demonstrated that it is possible for psychological data to satisfy at least some of the conditions of a deterministic theory of measurement. Thus it casts doubt upon Cliff’s (1992) argument that the problem of error makes it impossibly difficult to apply axiomatic conjoint measurement to psychological data. The present study suggests that it is possible to discover quantitative psychological attributes using axiomatic conjoint measurement provided sufficient care has been exercised over the construction of stimuli. Michell (1990) argued that the development of methods of stimulus control would occur concurrently with successful applications of axiomatic conjoint measurement. A method of stimulus control, the theory of the ordinal determinable, developed by Michell (1994a, 1998) was used successfully in the present study. Thus the results of the present study suggest that Michell’s theory itself is a valuable method of stimulus control.

A logical and potentially interesting extension of the present study would be to apply the quantitative methods employed here to other attributes involved in the development of impaired control over gambling. In their structural equation model of the attributes hypothesised to be involved in the addictive behaviour of gambling, Dickerson & Baron (2000) suggest that emotion, personality and level of involvement are all attributes contributing to the development of impaired control over gambling. Hitherto these attributes have been assumed to be quantitative. There does not appear to be any major hindrance or theoretical obstacle preventing the application of the methods employed in this thesis to these attributes. Such application could present some interesting findings and insights.

Moreover, the model proposed by Dickerson & Baron does allow for an extension of axiomatic conjoint measurement (Luce & Tukey, 1964) over its simple application to single unidimensional attributes. For example, the Dickerson & Baron (2000) model proposes that subjective control, coping and personality contribute to the level of involvement in gambling behaviour. An empirical study could possibly be designed such
that the relations between these identified attributes would take the form of axiomatic polynomial conjoint measurement (Krantz, et al, 1971; Krantz & Tversky, 1971). If level of involvement is taken to be the dependent variable, then a variety of forms of polynomial conjoint measurement could be employed given the variety of composition rules that could be empirically tested. Let $S, C, P$ and $I$ represent subjective control, coping, personality and level of involvement, respectively. An example composition rule could take the distributive form $I = S(C + P)$.

Such a composition rule is not theoretically implausible. Michell (1990) argues how Spence’s distributive model of learning may be tested using a polynomial conjoint measurement model. The empirical test of this distributive model of level of involvement, however, would necessarily be conducted after the prerequisite intensive research into the relevant personality traits and coping styles involved in addiction to gambling. Nevertheless, a polynomial conjoint model like the distributive one proposed above could, if the axioms are satisfied in an empirical test, provide a very strong theoretical means of linking together hitherto separate attributes within the area of gambling. Luce (personal communication)\(^{26}\) argued the theoretical power of axiomatic measurement theory lies in the capacity to formally link different structures together like in dimensional analysis in physics. Indeed, all quantitative structures in the natural sciences are theoretically linked together and as such there are none of the ‘free – standing’ attributes that pervade psychology. Conjoint measurement in its polynomial form could thus possibly achieve at least a tentative linking of the attributes proposed in the model of Dickerson & Baron (2000).

A more powerful extension of the present study would be to take the theory and methods employed here and apply them to the appetitive behaviours other than gambling. This would be especially important in the field of excessive consumption of alcohol, where the concept of subjective control was first proposed (Levine, 1978). An extension of the present study to this field would make for an especially interesting comparison. Unlike gambling, addiction to alcohol necessarily involves the introduction of a psychoactive chemical to the central nervous system; and so consequently, the nature of subjective control may not be the same as in gambling. If this were true, it would not support the argument made in Chapter 4 that the general definition of subjective control held for the other appetitive behaviours.

\(^{26}\) Email communication, 14\(^{th}\) September 2000.
Furthermore, the results of the present study may hold additional appeal for investigators in the area of addictive behaviour with respect to psychometric methodology. Chapter Four of this thesis demonstrated the ubiquitous use of factor analysis in the psychometric assessment of the various attributes associated with the alcohol dependence syndrome (ADS) (Edwards & Gross, 1976). Some of the pertinent studies that employed factor analysis have indeed shown that scale items pertaining to subjective control load upon a factor separate to all other factors (Chick, 1980a & b). This perhaps suggests that the concept of subjective control is sufficiently important to be assessed as a unidimensional attribute in its own right without regard to the ADS. Thus the methodological procedures and measurement theory employed in this thesis may be extended to the measurement of subjective control in addiction to alcohol in a rather straightforward manner.

Indeed, Edwards (1986) has encouraged the examination of subjective control as an attribute independent of the ADS. He did so, however, by extolling the use of factor analysis. The results of the present study, however, suggest that factor analysis produces solutions that are not consistent with the solutions of unidimensional unfolding theory (Coombs, 1964). Moreover, exploratory and confirmatory factor analyses conducted upon the Scale of Gambling Choices (SGC) (Baron et al, 1995) has shown that all such procedures achieve is a reduction in the number of items present in the scale. Appendix 19 contains an exposition of such research conducted upon the original 18 item and new 12 item (O’Connor, 2000) versions of the SGC which were administered to the participants of the present study. More damming, however, is that factor analysis appears to have a limited capacity to identify possible quantitative attributes. It was shown in this thesis to contradict the findings of axiomatic conjoint measurement (Luce & Tukey, 1964). This finding casts strong doubt upon factor analysis being a genuine method of psychological measurement.

It may be the case that because factor analysis has been used to such an extent, not all genuinely unidimensional attributes relevant to addiction to alcohol have been identified. Single dimensions may have been ‘split’ into two ostensibly separate dimensions similar to what was found in the present study regarding the two factor phenomenon (Coombs, 1964, 1975; Coombs & Kao, 1960). This is especially important with reference to the ADS (Edwards & Gross, 1976) for the following reason. Edwards (1986) argued the factor analysis model provided a legitimate test of the theory of the ADS itself:
"...the identification of a factor which loads on appropriate items might be taken as
validation of the syndrome concept, and the failure of any element to load on this dimension
might suggest that it is not part of the syndrome" (p.174).

Given the limitations of factor analysis, in particular the extra factor phenomenon, Edwards's argument is rather dangerous. It could lead to potentially great misunderstandings of the behaviours of the attributes concerned with addiction to alcohol.

The methods employed in this thesis could assist researchers in the area of addiction to alcohol to discover the truly unidimensional and quantitative attributes of concern to them. For example, Edwards (1986) presented the work of Chick (1980a & b) and Stockwell, et al, (1979) as exemplars of factor analytic work into the ADS. These two studies between them discovered the factors of physical withdrawal, affective withdrawal, withdrawal relief, rapidity of the reinstatement of symptoms, narrowing of drinking repertoire, salience and increased tolerance. There does not appear to be any theoretical problems which would preclude any of these unidimensional attributes from the kinds of analyses conducted in this thesis. Such analyses may provide for a starting point with respect to testing the attributes for additive structure.

This research into control and use of alcohol could be expanded as follows. Polynomial conjoint measurement (Krantz et al, 1971) could be brought to bear upon the attributes outlined within the ADS in a manner similar to that speculated earlier with the Dickerson & Baron (2000) model of gambling. For the same aforementioned reasons, a well conducted empirical application of polynomial conjoint measurement could lead to a more conceptually powerful understanding and measurement of the processes underlying impaired control of alcohol consumption. For example, take the factors of physical and affective withdrawal and withdrawal relief of (Stockwell et al, 1979). It is not implausible to hypothesise that such factors may pertain to a more general attribute of withdrawal. Let P and A represent physical withdrawal and affective withdrawal, respectively. If X represents this general withdrawal attribute, then a simple binomial conjoint measurement model of the form \( X = A + P \) could be tested in the first instance. Then a polynomial model of the distributive form \( X = (A + P) \cdot R \) could be tested; where R represents withdrawal relief. Or alternatively, a model of the form \( X = A \cdot R + P \cdot R \) could be tested. Thus polynomial conjoint measurement (Krantz & Tversky, 1971) could allow for the testing of a variety of composition rules with respect to the attribute of withdrawal alone.
The other appetitive behaviours identified by Orford (1985, 2000) could also be subject to empirical investigations similar to those conducted in the present study. Eating and the sexual behaviours are appetitive behaviours and like gambling do not involve the introduction of psychoactive chemicals to the central nervous system. Thus psychometric investigation of these other appetitive behaviours could benefit from the application of the theories and methods employed in the present study. The results of research like this could make for interesting comparisons between the appetitive behaviours of eating, gambling and sex, especially in regard to the attribute of subjective control. It would be interesting to see if the general definition of subjective control advanced in this thesis does indeed hold for these appetitive behaviours as it was argued to do in Chapter 4. Thus the extension of the theories and methodology of the present study to the other areas of addictive behaviour may have more than just an impact upon psychometric methodology employed. It may enable a better understanding of the nature of the attributes underpinning those behaviours; thus leading to a better understanding of the key psychological processes of the addictive experience.

In the previous chapter the serendipitous discovery of the exponential relationships between the transformed Goode's (1964, cited in Coombs, 1964) algorithm solutions and the transformed GHCM (Luo, 2001) and SHCM (Andrich & Luo, 1993) scaling solutions for each version of the Subjective Control scales was closely examined and discussed. To the best knowledge of the investigator, such systematic relationships between probabilistic and deterministic theories of unidimensional unfolding have hitherto not been demonstrated. These findings of the present study have several important ramifications. Firstly, the SHCM and GHCM theories of unfolding proposed by Andrich (1988b, 1989, 1995) and his associate Luo (1998, 2001) are consistent with the deterministic arguments of axiomatic conjoint measurement (Luce & Tukey, 1964). This is a rather important finding as these probabilistic theories do not have in themselves the ability to appropriately test an attribute for deterministic additive structure. That is, these models are designed to analyse data that is already in ostensibly numerical form, such as ratings data or the outcomes of a random Bernoulli variable in the case of paired comparisons. As such, these models assume that the underlying structure is quantitative (Luce, 1997). The findings of the present study suggest that this assumption may not be misplaced; and so consequently, are consistent with the argument that the SHCM and GHCM are genuine models of psychological measurement.
This conclusion concerning the GHCM and SHCM models of unidimensional unfolding probably has its greatest impact in the practical facet of psychological measurement. Coombs' (1964) theory is 'data hungry' in that a sufficient number of I scales must be produced by participants to enable the unfolding of a scaling solution. As participants' responses to paired comparison tasks contain intransitive judgements, data from ratings and ranking tasks are usually needed to 'correct' these intransitivities. This places additional demands upon the cognitive resources of participants. Additionally, the Coombs' procedure is rather cumbersome for the researcher if more than six stimuli or statements are involved. These practical limitations may constitute too much of an obstacle for researchers who may be operating under time and financial constraints. In such instances the SHCM and GHCM models of unfolding may provide a considerably easier method of scale construction in practical terms as compared to Coombs's (1964) theory of unfolding. On the basis of the present study, such researchers could employ these probabilistic theories in the knowledge that at least limited evidence has been found to suggest that these methods are genuine models of psychological measurement.

Another practical role the GHCM and SHCM models could perform would be in the pilot testing of statements constructed using the theory of the ordinal determinable (Michell, 1994a, 1998). The pilot tests of the present study found that Thurstone (1928) type studies of the unidimensionality of the statements were problematic. Participants seemed to be disoriented when asked to act as judges in the manner suggested by Thurstone. That is, they appeared to find it unusual not to report their own behaviour on the questionnaires, which obviously was their expectation. Hence the discovery in the rank order data of preference orders rather than unilateral orders. This problem could be bypassed in pilot studies if participants were asked to simply assess their agreement or disagreement with each statement on a Likert (1932) type scale. This data could then be processed by the general model of unfolding for polytomous responses (Luo, 1998, 2001) perhaps using the three available operation functions of the hyperbolic cosine, square (PARELLA) and square logistic. If the derived scaling solution located the statements upon the relevant continuum in the order predicted by the ordinal determinable (Michell, 1998), then the statements could be subject to further analysis using Coombs's (1964) theory. Thus the general unfolding model for polytomous responses may provide a considerably easier method of pilot testing statements than by conducting a traditional Thurstone type analysis.
The second important ramification of the finding of the exponential relationships is a highly theoretical one concerning the Archimedean ordered mathematical group of translations (Luce, 1987, 2001). The finding is consistent with the hypothesis that the SHCM and GHCM probabilistic models and Coombs’ (1964) deterministic theory conceptualise the additivity of psychological attributes differently; given that each conceptualises the underlying single peaked preference function differently. If this hypothesis is indeed true, then it is possible that the results of the present study suggest that subjective control possesses quantitative structure sufficient to be ratio scalable; given the arguments concerning the Archimedean ordered group. If this suggesting is true, then it follows that in the present study, different theories of unfolding, all of which are limited to providing person and item measurements unique up to affine transformations only, have jointly uncovered a much richer structure than either could on its own. This is indeed a deeply interesting speculation which future research could investigate more thoroughly than has been done in the present study.

If such replication research found systematic relationships like the exponential ones of the present study, the findings of that research and the present study could be brought to bear as evidence in an argument raised in Chapter 1. This argument concerned the work of Narens (1981a & b) upon the automorphic structures giving rise to the various scale types initially identified by Stevens (1946). Narens argued that the interval and ratio scale types were generated homomorphically in the set of the real numbers from the automorphic structures of two distinct surface level empirical relational structures. These Narens termed linear structures and Dedekind complete scalar structures, respectively. Michell (1990) criticised this argument by stating that the deeper level additive structure of a quantitative attribute necessarily meant that that particular attribute could be measured at either the interval or ratio level. If the results of the present study were indeed replicated in future research, then this would be evidence in support of Michell’s argument.

The safest conclusion that can be drawn from the present study is that much further work is required before any of the findings made here can be thought of as anything more than tentative. An aforementioned starting point for future research would be to expand further into the area of gambling addiction and thence into the area of addiction to alcohol. This would enable a comparison between two addictive behaviours; one of which involves the ingestion of a psychoactive chemical. The empirical scope of the Subjective Control scales could then be expanded to include eight statements. This would
necessarily entail further intensive research into the predicates that could be possibly used; as the construction of additional statements itself necessarily entails the introduction of further predicates into the binary tree structures. The problem of predicate specificity (Michell, 1998) may also again manifest itself, so intensive pilot testing of the revised scales would be needed. Pilot testing could involve the use of the GHCM (Luo, 1998, 2001) as a convenient means of checking the compliance of order of the statements in the produced scaling solution with order predicted by the ordinal determinable.

Such revised versions of the Subjective Control scales may result in an unfolded Coombs’s (1964) solution upon which the higher order cancellation condition of triple cancellation (Krantz, et al, 1971) of axiomatic conjoint measurement could be tested. This would be a far more powerful test of the additivity of subjective control than the tests of double cancellation used in the present study. It would also enable more available data points to be utilised if curve fitting exercises similar to the ones undertaken in the present study were conducted. The plotting of additional data points would lead to a better estimation of the function form of curvilinear figures given that such figures are actually found.

The investigation of the relationships between the GHCM and Goode’s algorithm scaling solutions may be improved by revising the Likert (1932) type response scale. The GHCM was developed by Luo (1998, 2001) to ostensibly operate with a four point rating scale design involving the semantic categories of ‘strongly agree’, ‘agree’, ‘disagree’ and ‘strongly agree’. The present study utilised an 11 point Likert (1932) rating scale design for the purpose of being able to correct intransitive pair comparisons. Merely ordinal information was obtained from the scales for this purpose. Using a scale of this size, however, might potentially lead to a bad fit of GHCM to the data. The 11 point scales used also contained a ‘neutral’ or non-response category. The GHCM was designed without this category as it has been found that such categories can cause problems of item data fit to models (Andrich, 1996), especially with the Rasch model for ordered response categories (Andrich, 1978). Future research may find it prudent to utilise the four point rating scale design for which the GHCM was ostensibly designed to deal with. This may lead to a better fit of the GHCM to the data than was the case in the present study, thus leading to a better estimation of functional forms in curve estimation tasks.

Factor analysis could also be conducted upon the rating scale data gathered in a future study on unfolding theories. This would be to further investigate the two factor phenomenon (Coombs, 1964, 1975; Coombs & Kao, 1960). If two factor solutions were
again evident, this would strongly suggest that factor analysis is quite limited in detecting attributes which are perhaps genuinely unidimensional. This would be strengthened if the study was conducted using eight statements as opposed to six. Moreover, if the ordered metric information from these eight statements satisfied the triple cancellation condition of conjoint measurement, then this would again demonstrate factor analysis to be inconsistent with conjoint measurement. Such a finding would be potentially fatal to the argument that factor analysis is a genuine method of psychological measurement.

In conclusion, subjective control is the key dependent variable of research into addictive behaviours (Dickerson & Baron, 2000). Indeed, it is difficult to conceptualise addictive behaviour without reference to this concept. Thus it is important enough to warrant further research as an attribute in its own right. Edwards (1986) suggested a need for greater scientific speculation and research into the addictive behaviours, particularly in regards to subjective control. This thesis heeded that suggestion and found tentative evidence consistent with the hypothesis that subjective control is a unidimensional, quantitative and thus measurable psychological attribute. This hypothesis may also hold within other addictive behaviours.

But perhaps the final conclusion to this thesis is political, not scientific. Luce (1997, p.80) stated that a strong reason why a genuinely quantitative science of psychology has not arisen is “...the failure, especially in the United States, of the psychometric and mathematical modelling communities to form a strong intellectual alliance. Both groups have exhibited considerable mutual disdain.” The relationships discovered in this thesis between deterministic and IRT theories of unfolding suggest that such an alliance between psychometrics and mathematical psychology may bear considerable scientific fruit. Perhaps only with the formation of this alliance could the first steps be taken towards a genuinely quantitative science of psychology.
Appendix 1: Initial pilot testing of the subjective control questionnaires

Aim
To see if the three sets of the six statements constructed using Michell’s (1998) theory of the ordinal determinable are unidimensionally ordered.

Empirical hypothesis
The set of six statements within each questionnaire are ordered unidimensionally as predicted by Michell’s (1998) theory of the ordinal determinable (for the ordinal determinable, predicates and statements please refer to Appendix 1a). This will be tested probabilistically using Thurstone’s (1928) theory of comparative judgment. Thurstone argued that for two stimuli x and y in a paired comparison task, the probability that x is chosen over y and vice versa is:

\[ \Pr[x|x, y] = \Phi(\mu_x - \mu_y) = 1 - \Pr[y|x, y] \]  

where \( \Phi(\mu_x - \mu_y) = \frac{1}{\sqrt{2\pi}} \int_{\mu_x - \mu_y}^{\infty} e^{-t^2/2} dt \)  

The problem with Eqn. 2 is that it is not a closed form distribution function (Train, 2002). Thus theoretical probabilities using this equation cannot be calculated algebraically (Andrich, 1978). However, Thurstone’s theory can be modified such that Eqn 2 is replaced by the logistic function \( y = \left(1 + e^{-x}\right)^{-1} \) such that the Rasch model for paired comparison tasks results:

\[ \Pr_{xy} = \frac{e^{(\alpha_x - \alpha_y)}}{1 + e^{(\alpha_x - \alpha_y)}} \]  

Equation 3 is a closed form distribution function that allows for the algebraic calculation of theoretical probabilities. The parameters \( \alpha_x \) and \( \alpha_y \) correspond to the unseen ‘discriminal processes’ (Thurstone, 1928) of x and y, respectively. In Eqn 3, these parameters locate the stimuli upon a latent continuum measured in natural logits.

Thurstone argued that any psychometric apparatus constructed using his theory of comparative judgement should not involve the personal preferences of the judges during the construction of the apparatus:

The statements should be such that acceptance or rejection of the statement does not indicate something regarding the reader’s attitude about the issue in question (1928, p.226).

In other words, the statements should be able to be ordered along a continuum via their semantic content alone and without reference to the personal preference of the people judging the statements. If this is achievable, then paired comparison data will fit the model in Eqn 3. Such a fit will indicate that the statements can be ordered via their
semantic content alone. This is exactly what Michell (1994a, 1998) contends the theory of the ordinal determinable does. Thus Eqn 3 permits a probabilistic test of statements constructed using Michell’s theory.

Method

Design
Unidimensional paired comparison questionnaire design. Each questionnaire consisted of 15 paired comparison tasks derived from 6 statements, making a total of 45 paired comparisons. Questionnaires were anonymous.

Participants
Students enrolled in first year psychology at the University of Western Sydney, Macarthur were the participants. Eight were male and 40 were female. The mean age was 21.15 years (S.D. = 6.91). The only criterion for their participation was that they had gambled at least once in their lives. All participants received course credit for their participation.

Materials
The statements initially proposed for the general, time involvement and impulses to gamble versions of the Subjective Control scales are listed below. The ordinal determinables, predicates and statements are shown in Appendix 1a.

Statements in the Subjective Control scale of general control over gambling

Statement A: I never experience any need to control my gambling at all as I just play when I want to.

Statement B: Although I feel a need to control my gambling, I enjoy it and can easily control it without any conscious effort; but I do think about cutting back from time to time.

Statement C: I feel a need to control my gambling and while it does take some effort, controlling it is relatively easy and as I enjoy my gambling, it doesn’t bother me.

Statement D: Although my gambling is relatively difficult to control, it causes few but only minor problems.

Statement E: My gambling is very difficult but not impossible to control, even though it causes several problems.

Statement F: My gambling is impossible to control and it causes several, significant problems that are very distressing.

Statements in the Subjective Control scale of control over time spent gambling
Statement A: I do not experience any need to limit the time I spend gambling and I spend as much time gambling as I want to.
Statement B: Although I feel a need to limit the time I spend gambling, I enjoy it and can easily limit it without conscious effort; but I do think about cutting back from time to time.
Statement C: I feel a need to limit the time I spend gambling and while it does take some effort, limiting it is relatively easy and as I am careful, I enjoy gambling.
Statement D: Although it is relatively difficult for me to limit the time I spend gambling, my gambling does not interfere with other activities.
Statement E: It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling interferes with other activities.
Statement F: It is impossible for me to limit the time I spend gambling and it interferes with other activities and causes significant problems that are very distressing.

Statements in the Subjective Control scale of control over urges to gamble
Statement A: I never experience strong impulses to gamble and I play when I wish to.
Statement B: I sometimes experience strong impulses to gamble, but I can easily resist them without any conscious effort.
Statement C: I sometimes feel strong impulses to gamble and while easily resisted, it does take some effort.
Statement D: I often have strong impulses to gamble that are difficult to resist, but not very difficult.
Statement E: The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes problems.
Statement F: My frequent, strong impulses to gamble are impossible to resist and my gambling causes significant problems that are very distressing.

Procedure
Participants were recruited using a notice posted on the Department of Psychology’s Notice board at both the Bankstown and Campbelltown campuses. Participants were asked to write their name on the notice sheet at times displayed on the sheet and to turn up at those times to the location of the study.
Participants were administered the questionnaires in groups. The researcher read the instructions out to the participants. Participants were told that there were three questionnaires to complete and that each questionnaire contained 15 boxes containing 2
statements each. These were the paired comparison tasks. Participants were told to tick the statement that they felt indicated a greater level of control over gambling. Participants were explicitly instructed not to indicate their own perceived control over their gambling behaviour on the questionnaires. This was done so that participants gave unidimensional orderings based on the semantic content of the statements rather than preference orderings based on their own personal experience.

Participants were told to complete the questionnaires at their own pace and to make all of the paired comparison judgments as accurately as possible. They were also told that there were no right or wrong answers. Once a participant finished he or she was free to leave.

**Results**

It was hypothesised that the statements within each questionnaire are ordered unidimensionally as predicted by Michell’s (1998) theory of the ordinal determinable. The hypothesis was not supported. The data from all three questionnaires did not fit the model of Eqn 3.

The responses made by all of the participants to each of the 3 questionnaires were assessed using paired comparison matrices. These matrices were of a 6 x 6 design. The columns were ordered from left to right following the ordering of statement A to statement F. Another column was added to the right of the column for statement F. This was the column for the row totals. The rows were ordered from top to bottom following the ordering of statement A to statement F. This design gave 15 boxes above the A,A; B,B;...F,F diagonal with which to record a participant’s responses to each of the 15 pair comparison judgments.

The convention followed in these matrices was to place a ‘1’ in boxes where the row statement was judged by the participant as indicating greater control over gambling than the column statement. If the participant indicated the column statement as indicating greater control then a ‘0’ was placed in the box. This was done for all of the boxes above the diagonal in each matrix. For example, if a participant judged statement D as indicating greater control over gambling than statement F by ticking statement D in the D/F paired comparison task, a ‘1’ was recorded in the D/F box of the paired comparison matrix.

When the participant’s responses to the paired comparison tasks were recorded in this way, the responses were reflected around each matrix’s diagonal. This means that each response recorded above the diagonal was recorded oppositely in the boxes below the
diagonal. For example, if the A/B box above the diagonal recorded a ‘1’, then the corresponding A/B box below the diagonal received a ‘0’. This was done for all 15 boxes below the diagonal. Then the row totals were taken and recorded in the totals column.

If a participant had judged that the 6 statements of each of the 3 questionnaires were ordered unidimensionally as per the ordinal determinable for each questionnaire, then the row total for statement A was 5, statement B, 4; statement C, 3 and so on to statement F which was 0. Please refer to Figure 1.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>*</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>*</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>0</td>
<td>*</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>*</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>*</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>*</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 1: A pair comparison matrix displaying a unidimensional ordering of statements A to F. Such a response was made by participant no. 25 to all questionnaires, the sole participant to do so.

It was found that the majority of participants did not respond in this way. Only 5 participants gave such an ordering for the general questionnaire. Only 1 gave a unidimensional ordering for the questionnaire that concerned the amount of time spent gambling. Eight gave unidimensional orderings for the questionnaire that concerned impulses to gamble. Only 1 subject gave unidimensional orderings for each of the 3 questionnaires.

It was found, however, that participants’ responses might have been contaminated by preference orderings. Preference orders were evident in responses made that displayed two certain characteristics. Firstly, a statement other than A received a row total of 5 and each of the other statements received either a row total of 4, 3, 2, 1 or 0. Secondly, that these other row totals were strictly decreasing monotonically from the statement which received the 5 row total. Please refer to Figure 2.
Eight participants gave such orderings for the general questionnaire. Thirteen gave such orderings for the time limit questionnaire. Ten gave such orderings for the impulsivity questionnaire. One subject gave such orderings for each of the 3 questionnaires. Hence it was a distinct possibility that despite explicit instructions to the contrary, many participants recorded their own gambling behaviour on the questionnaires. This was interpreted as indicating a procedural failure of the study to control for participants’ predisposition to give an account of their own behaviour.

Preference orders notwithstanding, a major source of error might have laid in the semantic content of the statements themselves. To examine this, pair comparison proportion matrices were constructed. Please refer to Figs. 3, 5 and 7.

These matrices are identical in structure to paired comparison matrices used to assess the responses of individual participants. In proportion matrices, however, the area below the diagonal is not used as is the row totals column. Responses of ‘1’ to each of the 15 boxes above the diagonal are tallied across all participants and a simple proportion frequency recorded in each box. This proportional frequency directly indicates how often each row statement in the matrix was judged as indicating greater control over gambling than the column statements. Paired comparison proportions matrices were constructed for each of the 3 questionnaires across all 48 participants.
Figure 3: Proportions matrix for the general questionnaire.

Figure 4: Null hypothesis tests of single and double cancellation of proportions for the general questionnaire. Double lines indicate equivalences, arrows indicate significant differences, with greater proportions at the head.

Figure 5: Proportions matrix for the time limit questionnaire.
Figure 6: Null hypothesis tests of single and double cancellation of proportions for the time limit questionnaire.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

Figure 7: Proportions matrix for the impulsivity questionnaire.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>*</td>
<td>.44</td>
<td>.48</td>
<td>.58</td>
<td>.60</td>
<td>.73</td>
</tr>
<tr>
<td>B</td>
<td>*</td>
<td>.63</td>
<td>.79</td>
<td>.77</td>
<td>.83</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>*</td>
<td>.77</td>
<td>.79</td>
<td>.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>*</td>
<td></td>
<td>.60</td>
<td>.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td>*</td>
<td>.88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

Figure 8: Null hypothesis tests of single and double cancellation of proportions for the impulsivity questionnaire.
Table 1. Logistic model data for the general questionnaire items

<table>
<thead>
<tr>
<th>Statements</th>
<th>Location in natural logits</th>
<th>Chi Square value (df = 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-2.12</td>
<td>19.865**</td>
</tr>
<tr>
<td>B</td>
<td>1.10</td>
<td>17.92**</td>
</tr>
<tr>
<td>C</td>
<td>.82</td>
<td>6.405*</td>
</tr>
<tr>
<td>D</td>
<td>.26</td>
<td>9.55**</td>
</tr>
<tr>
<td>E</td>
<td>-.2</td>
<td>10.05**</td>
</tr>
<tr>
<td>F</td>
<td>-1.78</td>
<td>15.36**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total (df = 10) = 39.89**</td>
</tr>
</tbody>
</table>

* p < .05, ** p < .01

Table 2. Logistic model data for the time limit questionnaire items

<table>
<thead>
<tr>
<th>Statements</th>
<th>Location in natural logits</th>
<th>Chi Square value (df = 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-.174</td>
<td>24.37**</td>
</tr>
<tr>
<td>B</td>
<td>.788</td>
<td>9.11*</td>
</tr>
<tr>
<td>C</td>
<td>1.042</td>
<td>7.4*</td>
</tr>
<tr>
<td>D</td>
<td>.795</td>
<td>2.05</td>
</tr>
<tr>
<td>E</td>
<td>-.220</td>
<td>13.31**</td>
</tr>
<tr>
<td>F</td>
<td>-1.596</td>
<td>20.76**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total (df = 10) 38.50**</td>
</tr>
</tbody>
</table>

* p < .05, ** p < .01

Table 3. Logistic model data for the impulsivity questionnaire items

<table>
<thead>
<tr>
<th>Statements</th>
<th>Location in natural logits</th>
<th>Chi Square value (df = 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.28</td>
<td>11.74**</td>
</tr>
<tr>
<td>B</td>
<td>.978</td>
<td>10.78**</td>
</tr>
<tr>
<td>C</td>
<td>.763</td>
<td>6.21*</td>
</tr>
<tr>
<td>D</td>
<td>-.2</td>
<td>5.03</td>
</tr>
<tr>
<td>E</td>
<td>-.27</td>
<td>4.71</td>
</tr>
<tr>
<td>F</td>
<td>-1.552</td>
<td>18.22**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total (df = 10) 27.16**</td>
</tr>
</tbody>
</table>

* p < .05, ** p < .01

The Rasch model analyses indicated participants' responses to the paired comparison tasks did not fit the model. From Tables 1, 2 and 3, it can be seen that Statement A was the most problematic statement. The item chi-square values of this statement were some of the highest of all the statements. In the general and time limit questionnaires, this statement was located below Statements B, C, D and E and B, C and D, respectively. This suggests that participants' interpreted Statement A as indicating less subjective
control over gambling behaviour rather than the greatest level of subjective control as predicted.

The results of the proportions matrices were quite revealing. As can be seen from Figs. 3, 5 & 7, the proportional frequencies increase both from the left of each matrix to the right and from the top of each matrix to the bottom. This general pattern is indicative of a problem with the ambiguity of statements as they progress towards indicating higher levels of control over gambling. The Rasch analyses supported this in that Statements B, C and D in the time limit questionnaire were not ordered along the continuum as expected. These findings strongly indicate these statements (with A in particular) suffered from ambiguity; either in its written expression or in the semantic content of its constituent predicates, or both.

In order to test the single and double cancellation conditions of additive conjoint measurement (Luce & Tukey, 1964) within each matrix, null hypothesis tests of proportions were conducted (see Ferguson, 1971, pp. 160-164). Michell's (1994, 1998) theory of the ordinal determinable and Thurstone's theory of comparative judgment (Thurstone, 1927, cited in Michell, 1990) predict the following pattern of ordinal relations between the proportions of six unidimensional statements:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

Figure 9: The order relation of '≽' upon the statement proportions satisfying single and double cancellation. Arrows are directed from proportions of less magnitude to those of greater magnitude.

As can be seen from Figs. 4, 6 and 8, the proportions in all matrices failed single cancellation. Hence all tests of double cancellation not independent of single cancellation also failed. The test of double cancellation independent of single cancellation, Luce-Tukey cancellation (Michell, 1994), was supported only by the data of the general questionnaire. Such failure indicates that either the statements are not ordered along a
single, quantitative dimension or that such a dimension has been obscured by excessive error during observation.

Overall, the results do not support the hypothesis. Both the Rasch analyses and patterns present in the proportions matrices indicate that the sets of statements were defective. The number of possible preference orderings given indicated a procedural failure in controlling extraneous factors. The Rasch analyses indicated that Statement A was a very problematic item.

Discussion

It was the aim of this study to assess the unidimensionality of statements created using Michell’s (1998) theory of the ordinal determinable. It was hypothesised that the statements would be unidimensionally ordered. This hypothesis was refuted.

The Rasch analyses demonstrated that statement A was severely defective in all three questionnaires. The statement was worded in the general questionnaire: *I never experience any need to control my gambling at all as I just play when I want to.* It was possible that such wording was seen as ambiguous. From participants’ responses, the statement was viewed as indicating the least control over gambling than any other statement. They quite possibly interpreted the statement as meaning that an individual had lost so much control over his or her gambling that attempts to control gambling were irrelevant. Unlike statements D, E and F, there was no specific reference made in statement A to problems caused by the level of control exerted over gambling. Hence statement A may have been viewed by participants as indicating that an individual gambler could no longer care about the problems that his or her gambling was causing. The statement did not contain an explicit predicate stating that gambling was not causing the individual problems, hence the absence of such a predicate may have been a possible source for this statement’s ambiguity. However, statements B and C did not contain such a predicate yet there was not as much confusion surrounding these statements. But these statements contained a predicate that was not present in statement A; and that was “I enjoy gambling”. Participants may have inferred the absence of this predicate in statement A to mean that individuals at the level of A do not enjoy their gambling. Hence statements B and C being judged as indicating greater levels of control over gambling than A.

In the time limit questionnaire, confusion did surround statements B and C. Statement B was worded: *Although I feel a need to limit the time I spend gambling, I enjoy it and can easily limit it without conscious effort; but I do think about cutting back from time to*
time. Statement C was worded: *I feel a need to limit the time I spend gambling and while it does take some effort, limiting it is relatively easy and as I am careful, I enjoy gambling.* Participants may have had trouble discriminating between these statements as the semantic content of their terminating predicates are ambiguous, especially that of statement C. These statements might have performed better if these predicates were either not present or their written expression altered. Participants had trouble discriminating between these statements and statement D and it may have been due to these statements not containing an explicit predicate stating that gambling was not causing problems. Additionally, these statements also contained the “I enjoy gambling” predicate which may have adversely affected judgements on statement A for the aforementioned reason.

Less confusion was present with statements A, B and C in the impulsivity questionnaire than in the other questionnaires. This was in spite of these statements not containing an explicit predicate stating that problems are not being experienced at these levels. But what was not present in statements B and C was the predicate “I enjoy my gambling”.

Thus the wording of these statements may have had less of an adverse affect upon statement A as perhaps indicated by the proportions matrix. Statement A, nevertheless, suffered from ambiguity like it did in the others.

Procedurally, the study failed to control the extraneous factor of participants’ giving preference orderings on the questionnaires. Given that the study was concerned with unidimensional orderings of the statements and thus had tailored the paired comparison procedures specifically to assess unidimensionality, the possible preference orderings given by many participants unavoidably caused a great deal of error. The assumption that explicit instructions to participants to make unidimensional orderings would be sufficient for them to actually do so was ill-founded. The study should have attempted to control for participants’ expectations by incorporating some method by which participants could record their own gambling behaviour. The study could have then proceeded to instruct participants for unidimensional orderings. This procedural amendment may have had the facility of reducing participants’ confusion in completing the questionnaires. If any participant then failed to make unidimensional orderings, that participant’s preference data given in the ratings task could be used to see whether or not the participant continued to make preference orderings in the paired comparison task. Thus error from preference orderings could be controlled as any preference orders given in the second
task could be checked and then removed from analysis. The present study did not have this facility at its disposal and hence suffered as a result.

Given the very poor performance of the questionnaires in this study, it was decided that a second pilot study be conducted to address the problems encountered in this study. These problems were, specifically, the semantic content of the predicates in the statements (and perhaps both the structure and the written expression of the statements themselves) and the procedural control of extraneous factors (such as preference orderings).
Appendix 1a: The ordinal determinables, tree structure diagrams, predicates and constructed statements used in the initial pilot study.

1.1a.1 The initial design of the Subjective Control scale of general control over gambling.

The predicates employed in the construction of the initial set of statements were as follows:

~Ex = I never experience any need to control my gambling at all; Pl = I play when I wish to; ~Pl = I do not play when I wish to; Co = My gambling behaviour is relatively easy to control; ~Tr = I do not have to make a conscious effort to control my gambling behaviour; En = I enjoy my gambling; ~En = I do not enjoy my gambling; ~Th = I do not even occasionally think about reducing me gambling activity; Th = I occasionally think about reducing my gambling behaviour; ~Con = My gambling behaviour is not cause for concern; Con = My gambling behaviour is cause for concern; Ex = I experience a need to control my gambling; ~Co = My gambling behaviour is relatively difficult to control; ~Spr = My gambling causes few problems; Spr = My gambling causes several problems; ~Si = My gambling causes problems of minor significance; Si = My gambling causes problems of significance; Vd = My gambling is very difficult to control; ~Vd = My gambling behaviour is not very difficult to control; Im = My gambling behaviour is impossible to control; ~Im = My gambling behaviour is not impossible to control; ~Di = My gambling causes significant problems that are not very distressing; Di = My gambling causes significant problems that are very distressing.

All possible terminal statements

\[
t_1 = \sim \text{Ex}. \text{Pl}
\]
\[
t_2 = \sim \text{Ex}. \sim \text{Pl}
\]
\[
t_3 = \text{Ex}. \text{Co}. \text{En}. \sim \text{Tr}. \sim \text{Th}
\]
\[
t_4 = \text{Ex}. \text{Co}. \text{En}. \sim \text{Tr}. \text{Th}
\]
\[
t_5 = \text{Ex}. \text{Co}. \text{En}. \text{Tr}. \sim \text{Con}
\]
\[
t_6 = \text{Ex}. \text{Co}. \text{En}. \text{Tr}. \text{Con}
\]
\[
t_7 = \text{Ex}. \text{Co}. \sim \text{En}
\]
\[
t_8 = \text{Ex}. \sim \text{Co}. \sim \text{Spr}. \sim \text{Si}
\]
\[
t_9 = \text{Ex}. \sim \text{Co}. \sim \text{Spr}. \text{Si}
\]
\[
t_{10} = \text{Ex}. \sim \text{Co}. \text{Spr}. \sim \text{Vd}
\]
\[
t_{11} = \text{Ex}. \sim \text{Co}. \text{Spr}. \text{Vd}. \sim \text{Im}
\]
\[
t_{12} = \text{Ex}. \sim \text{Co}. \text{Spr}. \text{Vd}. \text{Im}. \sim \text{Di}
\]
\[
t_{13} = \text{Ex}. \sim \text{Co}. \text{Spr}. \text{Vd}. \text{Im}. \text{Di}
\]

Terminal statements used as stimuli
A = t₁ = ~Ex. Pl

*I never experience any need to control my gambling at all and I play when I wish to.*

~Ex superimplies Pl, both are stated, Pl slightly colloquialised, giving:

*I never experience any need to control my gambling at all as I just play when I want to.*

B = t₄ = Ex. Co. En. ~Tr. Th

*I experience a need to control my gambling and My gambling is relatively easy to control and I enjoy my gambling and I do not have to make a conscious effort to control my gambling and I occasionally think about reducing my gambling activity.*

As Ex is subcontrary to Co, Co superimplies En, En is indifferent to ~Tr, ~Tr is indifferent to Th, Co & En are stated; Th is colloquialised; giving:

*Although I feel a need to control my gambling, I enjoy it and can easily control it without any conscious effort; but I do think about cutting back from time to time.*

C = t₅ = Ex. Co. En. Tr. ~Con

*I experience a need to control my gambling and My gambling is relatively easy to control and I enjoy my gambling and I do have to make a conscious effort to control my gambling and My gambling behaviour is not cause for concern.*

As Ex is subcontrary to Co, Co is indifferent to En; En is indifferent to Tr; Tr is subcontrary to ~Con; Ex and Co are not stated; Tr and ~Con are colloquialised; giving:

*I feel a need to control my gambling and while it does take some effort, controlling it is relatively easy and as I enjoy my gambling, it doesn’t bother me.*

D = t₆ = Ex. ~Co. ~Spr. ~Si

*I experience a need to control my gambling and My gambling behaviour is relatively difficult to control and My gambling causes few problems and My gambling causes few problems of minor significance.*

As Ex subimplies ~Co; ~Co subimplies ~Spr; ~Spr subimplies ~Si; Ex is not stated, ~Si is shortened and colloquialised; giving:

*Although my gambling is relatively difficult to control, it causes few but only minor problems.*

E = t₁₁ = Ex. ~Co. Spr. Vd. ~Im
I experience a need to control my gambling and My gambling behaviour is relatively difficult to control and My gambling causes several problems and My gambling is very difficult to control and My gambling is not impossible to control.

As Ex subimplies ~Co; ~Co subimplies Spr; Spr subimplies Vd; Vd is subcontrary to ~Im; Ex, ~Co are not stated; giving:

*My gambling is very difficult but not impossible to control, even though it causes several problems.*

\[ F = t_{13} = \text{Ex. ~Co. Spr. Vd. Im. Di} \]

I experience a need to control my gambling and My gambling behaviour is relatively difficult to control and My gambling causes several problems and My gambling is very difficult to control and My gambling is impossible to control and My gambling causes significant problems that are very distressing.

As Ex subimplies ~Co; ~Co subimplies Spr; Spr subimplies Vd; Vd subimplies Im; Im superimplies Di; Ex, ~ Co, Vd are not stated; Spr joined with Di; giving:

*My gambling is impossible to control and it causes several, significant problems that are very distressing.*

1.2 The initial design of the Subjective Control scale of control over time spent gambling.

The predicates employed in the construction of the initial set of statements were as follows:

~Ex = I do not experience any need to limit the time I spend gambling; Ex = I experience the need to limit the time I spend gambling; Pl = I spend as much time gambling as I wish to; ~Pl = I do not spend as much time gambling as I wish to; Ea = It is relatively easy for me to limit the time I spend gambling; ~Ea = It is relatively difficult for me to limit the time I spend gambling; ~Tr = I do not have to make a conscious effort to limit the time I spend gambling; Ca = I do not exercise care in my gambling; Ca = I do not exercise care in my gambling; ~Th = I do not even have to think about limiting the amount of time I spend gambling; Th = I occasionally think about limiting the amount of time I spend gambling.

~In = My gambling does not interfere with other activities; In = My gambling does interfere with other activities; Vd = It is very difficult for me to limit the time I spend
gambling; \( \sim V_d = \) It is not very difficult for me to limit the time I spend gambling; \( L_m = \) It is impossible for me to limit the time I spend gambling; \( \sim L_m = \) It is not impossible for me to limit the time I spend gambling; \( D_i = \) My gambling causes significant problems that are very distressing; \( \sim D_i = \) My gambling does not cause significant problems that are very distressing.

All possible terminal statements

\[ t_1 = \sim E_x. \ P_l \]
\[ t_2 = \sim E_x. \ \sim P_l \]
\[ t_3 = E_x. \ E_a. \ E_n. \ \sim T_r. \ \sim T_h \]
\[ t_4 = E_x. \ E_a. \ E_n. \ \sim T_r. \ T_h \]
\[ t_5 = E_x. \ E_a. \ E_n. \ T_r. \ C_a \]
\[ t_6 = E_x. \ E_a. \ E_n. \ T_r. \ C_a \]
\[ t_7 = E_x. \ E_a. \ \sim E_n \]
\[ t_8 = E_x. \ \sim E_a. \ \sim E_n \]
\[ t_9 = E_x. \ \sim E_a. \ I_n. \ \sim V_d \]
\[ t_{10} = E_x. \ \sim E_a. \ I_n. \ V_d. \ \sim L_m \]
\[ t_{11} = E_x. \ \sim E_a. \ I_n. \ V_d. \ L_m. \ \sim D_i \]
\[ t_{12} = E_x. \ \sim E_a. \ I_n. \ V_d. \ L_m. \ D_i \]

Terminal statements used as stimuli

\( A = t_1 = \sim E_x. \ P_l \)

I do not experience any need to limit the time I spend gambling and I spend as much time gambling as I wish to.

\( \sim E_x \) stated verbatim, \( P_l \) slightly colloquialised; giving:

I do not experience any need to limit the time I spend gambling and I spend as much time gambling as I want to.

\( B = t_4 = E_x. \ E_a. \ E_n. \ \sim T_r. \ T_h \)

I experience the need to limit the time I spend gambling and it is relatively easy for me to limit the time I spend gambling and I enjoy gambling and I do not have to make a conscious effort to limit the time I spend gambling and I occasionally think about limiting the amount of time I spend gambling.

As \( E_x \) is subcontrary to \( E_a \); \( E_a \) is indifferent to \( E_n \); \( E_n \) is indifferent to \( \sim T_r \); \( \sim T_r \) is indifferent to \( T_h \); \( E_x \) is not stated, \( E_a, \sim T_r \) and \( T_h \) are colloquialised; giving:
Although I feel a need to limit the time I spend gambling, I enjoy it and can easily limit it without conscious effort; but I do think about cutting back from time to time.

C = t₃ = Ex. Ea. En. Tr. Ca

I experience the need to limit the time I spend gambling and It is relatively easy for me to limit the time I spend gambling and I enjoy gambling and I have to make a conscious effort to limit the time I spend gambling and I exercise care in my gambling.

As Ex is subcontrary to Ea; Ea is indifferent to En; En is indifferent to Tr; Tr is indifferent to Ca; Ex & Ea are not stated, Tr and Ca are colloquialised; giving:

I feel a need to limit the time I spend gambling and while it does take some effort, limiting it is relatively easy and as I am careful, I enjoy gambling.

D = t₈ = Ex. ~Ea. ~In

I experience the need to limit the time I spend gambling and It is relatively difficult for me to limit the time I spend gambling and My gambling does not interfere with other activities.

Ex subimplies ~Ea; ~Ea is indifferent to ~In; Ex is not stated, ~Ea & ~In are colloquialised; giving:

Although it is relatively difficult for me to limit the time I spend gambling, my gambling does not interfere with other activities.

E = t₁₀ = Ex. ~Ea. In. Vd. ~Im

I experience the need to limit the time I spend gambling and It is relatively difficult for me to limit the time I spend gambling and My gambling does interfere with other activities and It is very difficult for me to limit the time I spend gambling and It is not impossible for me to limit the time I spend gambling.

As Ex subimplies ~Ea; ~Ea is indifferent to In; In superimplies Vd; Vd superimplies ~im; Ex, ~ Ea & Im are not stated; giving:

It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling interferes with other activities.

F = t₁₂ = Ex. ~Ea. In. Vd. Im. Di

I experience the need to limit the time I spend gambling and It is relatively difficult for me to limit the time I spend gambling and My gambling does interfere with other activities and It is very difficult for me to limit the time I spend gambling and It is
impossible for me to limit the time I spend gambling and My gambling causes significant problems that are very distressing.

As Ex subimplies ~Ea; ~Ea is indifferent to In, In superimplies Vd; Vd subimplies Im, Im subimplies Di; Ex, ~ Ea, Vd are not stated; giving:

*It is impossible for me to limit the time I spend gambling and it interferes with other activities and causes significant problems that are very distressing.*

1.3 The initial design of the Subjective Control scale of control over urges to gamble.

The predicates employed in the construction of the initial set of statements were as follows:

~Ex = I never experience strong impulses to gamble; Ex = I experience strong impulses to gamble; Pl = I play when I wish to; ~Pl = I do not play when I wish to; ~Of = I sometimes experience strong impulses to gamble; Of = I often experience strong impulses to gamble; Re = The strong impulses to gamble I experience are easy to resist; ~Re = The strong impulses to gamble that I experience are hard to resist; ~Tr = I do not have to make a conscious effort to resist the strong impulses to gamble that I experience; Tr = I have to make a conscious effort to resist the strong impulses to gamble that I experience; ~Vd = The strong impulses to gamble that I experience are very difficult to resist; ~Im = The strong impulses to gamble that I experience are not impossible to resist; Im = The strong impulses to gamble that I experience are almost impossible to resist; Pr = my gambling causes problems; ~Pr = My gambling does not cause problems; ~Di My gambling does not cause significant problems that are very distressing; Di = My gambling causes significant problems that are very distressing.

*All possible terminal statements*

\[ t_1 = \neg \text{Ex. Pl} \]
\[ t_2 = \neg \text{Ex. } \neg \text{Pl} \]
\[ t_3 = \text{Ex. Re. } \neg \text{Of. } \neg \text{Tr} \]
\[ t_4 = \text{Ex. Re. } \neg \text{Of. Tr} \]
\[ t_5 = \text{Ex. Re. Of} \]
\[ t_6 = \text{Ex. } \neg \text{Re. } \neg \text{Vd. } \neg \text{Of} \]
\[ t_7 = \text{Ex. } \neg \text{Re. } \neg \text{Vd. Of} \]
\[ t_8 = \text{Ex. } \neg \text{Re. Vd. } \neg \text{Of} \]
\[ t_9 = \text{Ex. } \neg \text{Re. Vd. Of. } \neg \text{Im. } \neg \text{Pr} \]
\( t_{10} = \text{Ex. } \sim \text{Re. Vd. Of. } \sim \text{Im. Pr} \)
\( t_{11} = \text{Ex. } \sim \text{Re. Vd. Of. Im. } \sim \text{Di} \)
\( t_{12} = \text{Ex. } \sim \text{Re. Vd. Of. Im. Di} \)

*Terminal statements used as stimuli*

A = \( t_1 = \sim \text{Ex. Pl} \)

*I never experience strong impulses to gamble and I play when I wish to.*

\~\text{Ex} superimplies \text{Pl}; \text{Pl} is colloquialised; giving:

*I never experience strong impulses to gamble and I play when I wish to.*

B = \( t_3 = \text{Ex. Re. } \sim \text{Of. } \sim \text{Tr} \)

*I experience strong impulses to gamble and The strong impulses to gamble I experience are easy to resist and I sometimes experience strong impulses to gamble and I do not have to make a conscious effort to resist the strong impulses to gamble that I experience.*

\text{Ex} subimplies \text{Re}; \text{Re} is indifferent to \~\text{Of}; \~\text{Of} is subcontrary to \~\text{Tr}; \text{Ex} is not stated, \~\text{Of} is abbreviated, \~\text{Tr} is colloquialised; giving:

*I sometimes experience strong impulses to gamble, but I can easily resist them without any conscious effort.*

C = \( t_4 = \text{Ex. Re. } \sim \text{Of. Tr} \)

*I experience strong impulses to gamble and The strong impulses to gamble I experience are easy to resist and I sometimes experience strong impulses to gamble and I have to make a conscious effort to resist the strong impulses to gamble that I experience.*

\text{Ex} subimplies \text{Re}; \text{Re} is indifferent to \~\text{Of}; \~\text{Of} is indifferent to \text{Tr}; \text{Ex} and \text{Re} are not stated, \text{Tr} and \~\text{Of} are colloquialised; giving:

*I sometimes feel strong impulses to gamble and while easily resisted, it does take some effort.*

D = \( t_6 = \text{Ex. } \sim \text{Re. } \sim \text{Vd. } \sim \text{Of} \)

*I experience strong impulses to gamble and The strong impulses to gamble I experience are difficult to resist and The strong impulses to gamble that I experience are not very difficulty to resist and I often experience strong impulses to gamble.*

\~\text{Re} subimplies \~\text{Vd}; \~\text{Vd} subimplies \~\text{Vd}; \~\text{Vd} is indifferent to \text{Of}; \text{Ex} & \~\text{Vd} are not stated, giving:

*I often have strong impulses to gamble that are difficult to resist, but not very difficult.*
E = t_{10} = \text{Ex.} \neg \text{Re.} \text{ Vd.} \text{ Of.} \neg \text{Im.} \text{ Pr}

I experience strong impulses to gamble and the strong impulses to gamble I experience are difficult to resist and the strong impulses to gamble that I experience are very difficult to resist and I often experience strong impulses to gamble and my gambling does cause problems.

Ex subimplies \neg \text{re}; \neg \text{re} subimplies \text{Vd}; \text{Vd} is indifferent to \text{Of}; \text{Of} is indifferent to \text{Pr}; giving:

The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes problems.

F = t_{12} = \text{Ex.} \neg \text{Re.} \text{ Vd.} \text{ Of.} \text{ Im.} \text{ Di}

I experience strong impulses to gamble and the strong impulses to gamble I experience are difficult to resist and the strong impulses to gamble I experience are very difficult to resist and I often experience strong impulses to gamble and the strong impulses to gamble that I experience are impossible to resist and my gambling gambling causes significant problems that are very distressing.

Ex subimplies \neg \text{re}; \neg \text{re} subimplies \text{Vd}; \text{Vd} is indifferent to \text{Of}; \text{Of} is indifferent to \text{Im}; \text{Im} is indifferent to \text{Di}, \text{Ex} and \neg \text{Re} are not stated; \text{Of} and \text{Im} are joined and colloquialised; \text{Di} stated verbatim; giving:

My frequent, strong impulses to gamble are impossible to resist and my gambling causes significant problems that are very distressing.
Binary tree diagram of the ordinal determinable of the general Subjective Control Scale.
Binary tree diagram of the ordinal determinable of the time involvement Subjective Control Scale
Binary tree diagram of the ordinal determinable of the impulses to gamble Subjective Control Scale
Appendix 2: Secondary pilot testing of the revised subjective control scales

Aim:
To see if the revised set of statements constructed in light of the findings of the initial pilot study one are unidimensionally ordered as predicted by Michell’s (1998) theory of the ordinal determinable. For the revised ordinal determinables, predicates and statements please refer to Chapter 5.

Empirical Hypothesis
The revised set of statements in each of the three questionnaires are unidimensionally ordered as predicted by Michell’s (1998) theory of the ordinal determinable. The tests of the empirical hypothesis were the Rasch logistic paired comparison model and the cancellation axioms of conjoint measurement (Luce & Tukey, 1964) as per the initial pilot study.

Method
Design
Two part anonymous questionnaire design. Part one of the questionnaire was designed to control for participants’ preference responses. It utilised an 11 – point Likert methodology with 0 – 2 being “very partially explains”; 2 – 4 “partially explains”; 4 –5 “moderately explains”; 6 – 8 “strongly explains” and 8 – 10 “very strongly explains”. Each Likert scale was located underneath each statement in each of three questionnaires. Participant were instructed that ‘0’ meant that the statement did not explain their behaviour at all and ‘10’ meant that the statement totally explained their behaviour.

Part two of the questionnaire consisted of the same unidimensional pair comparison tasks used in the previous study, with 15 such tasks for each questionnaire, making 45 tasks in total.

Participants
First year psychology students at the University of Western Sydney, Macarthur were the participants. Forty – one were female and 10 were male. The participants’ mean age was 22.96 years (SD = 7.63). The only criterion for their participation was that they had gambled at least once in their lives. All participants received course credit for their participation.

Materials
The revised sets of statements for the general, time involvement and impulses to gamble versions of the Subjective Control scales are listed below. The ordinal determinables, predicates and statements are shown in Chapter 5.
Statements of the Subjective Control scale of general control over gambling

Statement A: I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.

Statement B: Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.

Statement C: I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems although I do think about cutting back from time to time.

Statement D: Although my gambling is relatively difficult to control, it causes few but only minor problems.

Statement E: My gambling is very difficult but not impossible to control, even though it causes several problems.

Statement F: My gambling is impossible to control and it causes several, significant problems that are very distressing.

Statements of the Subjective Control scale of control over time spent gambling

Statement A: I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

Statement B: Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

Statement C: I feel a need to limit the time I spend gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

Statement D: It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

Statement E: It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

Statement F: It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

Statements of the Subjective Control of control over urges to gamble

Statement A: I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.
Statement B: I sometimes experience strong impulses to gamble, but I can easily resist them without any conscious effort and my gambling does not cause any problems.

Statement C: I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause any problems.

Statement D: I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

Statement E: The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

Statement F: My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

Procedure

Participants were recruited using a notice posted on the Department of Psychology’s Notice board on the Bankstown campus. Participants were asked to write their name on the notice sheet at times displayed on the sheet and to turn up at those times to the location of the study. The study was conducted in a small office at the Bankstown campus.

Participants were administered the questionnaire in groups of 5. Participants were instructed to first complete the first part of the questionnaire and not to commence the second task until all of them had completed the first task. Participants were asked to rate each statement in terms of how well it explained their gambling experience. This was to control for participants’ predisposition to completing questionnaires by assessing their own behaviour. It was thought that this would make the unidimensional paired comparison task clearer to participants and thus reduce the number of participants giving preference orders.

Once all participants in the group had completed the first task, the instructions for the second task were read out by the researcher. The second task was an unidimensional paired comparison task identical to that administered in the previous study. Participants were again instructed to complete each pair comparison task by ticking the statement they felt indicated a greater level of control over gambling. But this time, it was made explicit that participants were not assess their own behaviour as this was asked of them in the previous task. Participants were explicitly instructed to base their judgments on the content of the statements themselves and nothing else. They were asked to complete the questionnaires at their own pace and to make their judgments as accurately as possible.
Results

It was hypothesized that the revised statements in each questionnaire would display a unidimensional ordering as predicted by Michell’s (1998) theory of the ordinal determinable.

The hypothesis was not supported.

The responses made by all 51 participants to each of the three revised questionnaires were assessed using the paired comparison matrices used in the first study. Participants’ responses to the revised questionnaires were considerably better than those given in the previous study, however, responses were again contaminated by error.

Ten participants gave unidimensional orderings for the general questionnaire. Sixteen responded as such to the time limit questionnaire. Seventeen gave such orderings for the impulsivity questionnaire. Of these participants, 6 gave unidimensional orderings for all three questionnaires.

Error responses were also analysed. Some participants had incorrectly responded to only one of the 15 paired comparison tasks in one of the three questionnaires. These responses were termed mildly intransitive orderings. Five participants gave such orderings for the general questionnaire. Three responded as such to the time limit questionnaire. Five responded as such to the impulsivity questionnaire. For the time limit and impulsivity questionnaires, two participants gave transitive, reverse unidimensional orderings (that is, statement F received a row total of 5). One of these participants had also given a mildly intransitive reverse ordering for the general questionnaire.

Participants who gave preference orderings in the paired comparison tasks could now be identified through the ratings tasks they completed initially. The rating task data for all 3 questionnaires, however, was greatly contaminated with error. The inherent design of rating scales allows either unilateral or bilateral pairs of statements to be given tied ratings. Tied ratings on unilateral pairs is of no concern if the unidimensional order of the statements is known (Michell, 1998), but as the current statements have not demonstrated unidimensionality, such tied ratings are important. Forty - nine participants gave tied ratings for the general questionnaire, 46 of these making more than one tied rating. Only 2 did not tie their ratings but they both failed to give transitive preference orders. All participants made tied ratings for the time limit questionnaire, with 46 making more than one tied rating. Forty - nine participants made tied ratings for the impulsivity questionnaire with 43 of them making more than one tied rating. Two participants did not
tie their ratings and one of them gave the transitive preference order of BCADF (Coombs, 1964). The other gave an intransitive ordering.

Only one subject could be identified using the ratings task as possibly giving a preference ordering for the general questionnaire. The ratings task, however, did not prevent possible preference orderings being present in the paired comparison task. Possible preference orderings given that were not verified by participants' responses to the ratings task totalled 8 for the general questionnaire. Five participants gave such orderings for the time limit questionnaire and 8 gave such orderings for the impulsivity questionnaire. This was interpreted as perhaps indicating that the ratings task did not work as a control for preference orderings in the paired comparison task.

Given this error, pair comparison proportions matrices were constructed as per the previous study. Such matrices were constructed for each of the three questionnaires across all 51 participants. Please refer to Figs. 6, 8 and 10.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>*</td>
<td>.61</td>
<td>.47</td>
<td>.67</td>
<td>.63</td>
<td>.80</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>*</td>
<td>.59</td>
<td>.78</td>
<td>.76</td>
<td>.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>*</td>
<td>.86</td>
<td>.82</td>
<td>.90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>*</td>
<td>.73</td>
<td>.84</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td>*</td>
<td>.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 6: Proportions matrix for the revised general questionnaire.
Figure 7: Null hypothesis tests of single and double cancellation for the proportions in Figure 6.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

Figure 8: Proportions matrix for the revised time limit questionnaire.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>.67</td>
<td>.84</td>
<td>.80</td>
<td>.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td>.82</td>
<td>.90</td>
<td>.84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td>.65</td>
<td>.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td>.84</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

Figure 9: Null hypothesis tests of single and double cancellation for the proportions in Figure 8.
Table 1. Logistic model data for the general questionnaire items

<table>
<thead>
<tr>
<th>Statements</th>
<th>Location in natural logit</th>
<th>Chi Square value (df = 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.492</td>
<td>6.51*</td>
</tr>
<tr>
<td>B</td>
<td>.607</td>
<td>11.71**</td>
</tr>
<tr>
<td>C</td>
<td>.776</td>
<td>8.71*</td>
</tr>
<tr>
<td>D</td>
<td>-.071</td>
<td>11.91**</td>
</tr>
<tr>
<td>E</td>
<td>-.333</td>
<td>11.41**</td>
</tr>
<tr>
<td>F</td>
<td>-1.471</td>
<td>10.01**</td>
</tr>
</tbody>
</table>

Total (df = 10) 30.19**

*p < .05, ** p < .01
Table 2. Logistic model data for the time limit questionnaire items

<table>
<thead>
<tr>
<th>Statements</th>
<th>Location (natural logits)</th>
<th>Chi Square value (df = 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.827</td>
<td>4.86</td>
</tr>
<tr>
<td>B</td>
<td>.945</td>
<td>4.81</td>
</tr>
<tr>
<td>C</td>
<td>.703</td>
<td>10.68**</td>
</tr>
<tr>
<td>D</td>
<td>-.334</td>
<td>5.3</td>
</tr>
<tr>
<td>E</td>
<td>-.616</td>
<td>8.22*</td>
</tr>
<tr>
<td>F</td>
<td>-1.524</td>
<td>8.49*</td>
</tr>
<tr>
<td>Total (df = 10)</td>
<td>21.18*</td>
<td></td>
</tr>
</tbody>
</table>

* p < .05, ** p < .01

Table 3. Logistic model data for the impulsivity questionnaire items

<table>
<thead>
<tr>
<th>Statements</th>
<th>Location (natural logits)</th>
<th>Chi Square value (df = 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.740</td>
<td>5.72</td>
</tr>
<tr>
<td>B</td>
<td>.681</td>
<td>6.23*</td>
</tr>
<tr>
<td>C</td>
<td>.485</td>
<td>5.51</td>
</tr>
<tr>
<td>D</td>
<td>-.06</td>
<td>6.63*</td>
</tr>
<tr>
<td>E</td>
<td>-.404</td>
<td>7.39*</td>
</tr>
<tr>
<td>F</td>
<td>-1.440</td>
<td>8.21*</td>
</tr>
<tr>
<td>Total (df = 10)</td>
<td>20.82*</td>
<td></td>
</tr>
</tbody>
</table>

* p < .05

The results of the Rasch analyses indicated that the revision of the statements trialed in the initial pilot study lead to substantial improvement in participants responses. Overall model chi-square values indicate that the Rasch model was again of a poor fit to the data. Individual item chi-square values, however, were noticeably reduced and the number of items with non-statistically significant chi-square values were increased. Statement A did not possess a negative logit location upon the latent continuum in any of the three questionnaires. Only the statements in the impulsivity questionnaire, however, were ordered as predicted by the ordinal determinable. In the time limit and general questionnaires, Statement B and Statements B and C, respectively, were judged as indicating greater subjective control over gambling than Statement A. This suggested that Statement A remained a problematic statement.

These results reveal a very similar pattern of matrix proportional frequencies to that of the previous study. Statement A remained the most problematic statement although it fared a great deal better in all three questionnaires than it did in the previous study. This
improvement was most marked in the time limit questionnaire. Here statement A was judged as indicating greater control over gambling than statement B by just under 60% of participants; compared to just under 20% of participants in the previous study. Statement A in this questionnaire made similar improvements with statements B, C, D and E. Only a modest improvement was gained with statement F. Statements D and E also improved quite markedly in this questionnaire compared to the previous study, the biggest improvements being with statement A. The D/E proportion, however, was worse in this study than in the previous one.

Statement A made only modest improvement in the other two questionnaires. The proportions between all other statements in these questionnaires remained largely unchanged compared to the previous study. Some proportions were worse, the most noticeable of these being the statement B / statement C comparison in the general questionnaire. Seventy – one percent of participants in the first study judged B as indicating greater control than C and this declined to 59% in the present study. Most of the other proportions for this questionnaire made only mild improvements. The questionnaire least affected by the revision was the impulsivity questionnaire, the only mild gains being with the A/B, A/C and A/E proportions.

In order to test the single and double cancellation conditions of additive conjoint measurement (Luce & Tukey, 1964) within each matrix, null hypothesis tests of proportions were conducted. In Fig. 7, the proportions failed all instances of double cancellation and thus single cancellation. In Fig. 9, the proportions satisfied Luce-Tukey double cancellation, but violated all other instances of double cancellation; thus violating single cancellation. The proportions in Fig. 11, however, satisfied all tests of double cancellation (see Michell, 1990, Table 5.3, Pattern 7, p.105) and thus single cancellation. These results are no clearer than those found in the previous study. The failure of cancellation conditions in Figs. 7 & 9 again indicates that either the statements are not ordered along a single, quantitative dimension or that such a dimension has been obscured by excessive error during observation. The satisfaction of all cancellation conditions in Fig 11 must be interpreted cautiously what has been discovered is that a non-ordinal equivalence relation holds upon the proportions. A standard sequence for the measurement of these proportions is thus impossible.

The greatly increased number of participants who made transitive unidimensional orderings was interpreted as indicating that moderate improvement was gained with the alteration of the statements. This interpretation was supported by the proportions
matrices. Improvement was most noticeable with the time limit questionnaire. From the relative lack of improvement the impulsivity questionnaire received from the revision it was interpreted that only minor gains could be made with further alteration of the statements. Importantly, the study suffered procedural failure in the prevention of preference responses being made in the paired comparison task. These results suggest that the design of the questionnaire was seriously flawed despite the attempt to control for preference responses. The results were still contaminated by so much error that the hypothesis remained unsupported.

Discussion

It was the aim of this study to assess the unidimensionality of the revised statements created using Michell’s (1998) theory of the ordinal determinable. It was hypothesised that the statements in each questionnaire would be unidimensionally ordered. This hypothesis was refuted.

Unlike the previous study, however, participants responses could be divided roughly into 3 groups: a/ those who gave transitive and mildly intransitive orderings; b/ those who gave possible preference orderings and c/ those whose data were thoroughly error ridden. In the first study such a grouping was not possible due to the entire data being thoroughly error-ridden.

The results of the present study suggest two things. Firstly, that the revision of the statements led to less confusion in participants’ ability to order them along a single dimension. Taking the problematic statement A in the general questionnaire as an example, the revision of A from *I never experience any need to control my gambling at all as I just play when I want to* into *I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all* certainly made A much less ambiguous. Given the presence of the predicate “does not cause problems” in the revised statement A, it would be very reasonable to suggest that this predicate would lead to an increased probability that participants would rate A as indicating greater control over gambling than statements D, E and F, which all contained the predicate “does cause problems”. The data does indeed reflect this, especially for the time limit questionnaire.

Secondly, that the method of collecting data on the questionnaires was highly problematic. That the revision of statements alone did not entirely eliminate erroneous responses supports this conclusion. It appears that the paired comparison task may have been too difficult for the type of participants used in both studies. Participants were only
in their first semester at university and were partaking in the research for course credit. All had never encountered a paired comparison procedure before and for many the studies were the first they were participating in to receive course credit. This lack of experience and the strong cultural expectation that one is going to be asked about one’s own behaviour when one is approached to complete a questionnaire may have led to great confusion as to how to make unidimensional paired comparisons. It may be too difficult for such participants to do correctly. This suggests that a further study will have to operate within participants’ limitations. That is, will have to seek unidimensionality of the statements in each questionnaire through asking participants to give their preferences.

Two other problems with participants may have been occurring. Firstly, many participants appeared to make ad-hoc or careless responses. This may have been consequential of the aforementioned difficulty of the unidimensional paired comparison procedure. The procedure of the present study only asked participants to make their judgments as accurately as possible and the researcher did not occasionally check the responses made by participants when they had completed the tasks. This allowed participants to receive their course credit regardless of how carefully they had made their responses. Secondly, that the location of the study may have had an influence. Participants were seated at a rather small table and could quite easily see the responses being made by other participants. This may have led to some participants making erroneous judgments despite explicit instructions to the contrary that responses to the questionnaires should be the participant’s own. A further study would have to remedy this by administering the questionnaires in a more appropriate venue.

The data derived from the ratings task supports previous concerns of the facility of the ratings procedure to produce tied ratings of statement pairs (Michell, 1998). This facility greatly disadvantaged the present study as evidenced by the lone participant who was able to give a transitive preference order for the impulsivity questionnaire. Given, however, that participants’ responses to ratings scales are largely guided by the semantic categories of the scales themselves, it was possible that the semantic categories used in the present study contributed to the erroneous data. These categories were ordered in terms of how well each statement explained the gambling experience of the participant. Given that the statements only pertained to control over gambling, it was possible that these categories contributed the erroneous data in that control is only a part of an individual’s gambling experience. Usually, rating scale categories are ordered in terms of agreement and disagreement. The use of these latter categories may be of benefit to a
future study as these categories may guide participants to rate that part of their gambling experience that the statements purport to address (i.e. choice/control), rather than attempt to rate the entirety of their gambling experience.

It would seem that on the basis of the results of the present study that a further revision of the statements would not bring about any significant improvements. It is hard to see how statement A in all three questionnaires could be rewritten to convey a stronger idea of complete and unconscious control over gambling. What could be improved is the design of the study itself. If a further study is to be conducted with first year psychology students, it would appear necessary to discard the unidimensional paired comparison procedure. This procedure appears to be far too demanding for participants to execute correctly. There appears to be a strong predisposition amongst participants to assess their own behaviour on the questionnaires, even though they have been explicitly instructed not to do this. It would be prudent for a future study to exploit this tendency and accept participants' limitations. If the statements within each questionnaire then fail to exhibit unidimensionality then the statements and possibly the ordinal determinable used to make them would have to be discarded and new statements written.
Appendix 3: Final pilot testing of the revised Subjective Control scales

Aim

To see if the three sets of six revised statements constructed using Michell’s (1998) theory of the ordinal determinable are unidimensionally ordered.

Empirical hypothesis

The set of six revised statements within each questionnaire are ordered unidimensionally as predicted by Michell’s (1998) theory of the ordinal determinable. As this study elicited individual preference data, the Rasch logistic model for paired comparison data was not available for use. Instead, the probabilistic unfolding models for paired comparison (Andrich, 1996, 1997) and rating scale (Luo, 2001) data were used.

Given the manifest Bernoulli variable of ‘Agree/Disagree’, \( X_{ni}, x_{ni} \in \{0,1\} \), the simple hyperbolic cosine model (SHCM) for dichotomous responses is:

\[
Pr[x_{ni} = 1] = \frac{\exp(\theta_i)}{\exp(\theta_i) + 2 \cosh(\beta_n - \delta_i)}
\]

where \( \theta_i \) is the unit parameter of statement \( i \) and \( \cosh(x) = \frac{\exp(-x) + \exp(x)}{2} \) (Andrich & Luo, 1993).

The general unfolding model for polytomous items (Luo, 2001) is exactly the same as the presented in Chapter 6. Not only is the hyperbolic cosine function employed, however. The square logistic function \( \psi(x) = \exp(x)^2 \) and the square (PARELLA) function \( \psi(x) = x^2 \) are also utilised. This enables the rating scale unfolding model to test which function best fits the observed data.

Both the rating scale and paired comparison unfolding models will be used to probabilistically test the unidimensionality of the 6 statements present in each questionnaire.

Method

Design

Two part anonymous questionnaire design. Part one utilised the same 11 – point Likert methodology of the previous study but the semantic categories of the scale were changed; with 0 – 2 being “strongly disagree”; 2 – 4 “disagree to some extent”; 4 – 6 “fairly neutral”; 6 – 8 “agree to some extent” and 8 – 10 “strongly agree”. Each Likert scale was located underneath each statement in each of the three questionnaires. Participants were
instructed that ‘0’ meant that they totally disagreed with the statement and ‘10’ meant that they totally agreed with the statement.

Part two consisted of unilateral preference pair comparison tasks. These differed greatly from the unidimensional paired comparisons used in the previous studies. The unilateral preference procedure consists of listing the statements from A to B of each questionnaire and asking participants to select the statement that is closest to their own preference. That is, participants select the statement they agree with the most. They then go on to complete pair comparison tasks, ticking the statement in each pair that they agree with the most. In unilateral pair comparisons, however, the number of paired comparisons needed to ascertain an order from A to F varies according the preferred statement of the individual participant. The number and type of paired comparisons needed to be made are as follows:

Statement A is preferred: All 15 pair comparison tasks to be completed.

Statement B is preferred: Pairs AB, BC, BD, BE, BF, CD, CE, CF, DE, DF, EF to be completed.

Statement C is preferred: Pairs AB, AC, BC, CD, CE, CF, DE, DF, EF to be completed.

Statement D is preferred: Pairs AB, AC, AD, BC, BD, CD, DE, DF, EF to be completed.

Statement E is preferred: Pairs AB, AC, AD, AE, BC, BD, BE, CD, CE, DE, EF to be completed.

Statement F is preferred: All 15 pair comparison tasks to be completed.

Participants

Students enrolled in first year psychology at the University of Western Sydney were the participants. Thirty – one participants were female and 10 were male. The mean age was 19.51 years (S.D = 3.36). The only criterion for their participation was that they had gambled at least once in their lives. All participants received course credit for their participation.

Materials

The revised sets of statements for the general, time involvement and impulses to gamble versions of the Subjective Control scales are listed below. The ordinal determinables, predicates and statements are shown in Chapter 5.

Statements of the Subjective Control scale of general control over gambling

Statement A: I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.
Statement B: Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.

Statement C: I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems although I do think about cutting back from time to time.

Statement D: Although my gambling is relatively difficult to control, it causes few but only minor problems.

Statement E: My gambling is very difficult but not impossible to control, even though it causes several problems.

Statement F: My gambling is impossible to control and it causes several, significant problems that are very distressing.

Statements of the Subjective Control scale of control over time spent gambling

Statement A: I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

Statement B: Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

Statement C: I feel a need to limit the time I spend gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

Statement D: It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

Statement E: It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

Statement F: It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

Statements of the Subjective Control scale of control over urges to gamble

Statement A: I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

Statement B: I sometimes experience strong impulses to gamble, but I can easily resist them without any conscious effort and my gambling does not cause any problems.

Statement C: I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause any problems.
Statement D: I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

Statement E: The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

Statement F: My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

Two specialist computer programs were used to analyse the rating scale data and the paired comparison data. These were, respectively RATEfold 2002 Version 2.0.3 (Luo and Andrich, 2002) and RUMMFOLDpp Version 2.1 (Andrich & Luo, 1998). All analyses were conducted by the author on a Intel Celeron PC.

Procedure

Participants were recruited using a notice posted on the Department of Psychology’s Notice board at the Bankstown campus. Participants were asked to write their name on the notice sheet at times displayed on the sheet and to turn up at those times to the location of the study. The study was conducted in the Family Therapy Centre at the Bankstown campus.

Participants were administered the questionnaire in groups of 5. Because a different venue was used to the previous studies, participants sat on chairs spaced widely apart and used clipboards to rest the questionnaire on instead of a small table. This made it difficult for participants to see each other’s responses.

Participants were instructed to complete the first part of the questionnaire and not to commence the second task until all of them had completed the first task. Participants were asked to rate each statement in terms of how much they agreed with it.

Once participants had completed the first task, the instructions for the second task were read out by the researcher. The second task was the unilateral preference paired comparison procedure. Participants were instructed to carefully read through the list of statements A to F of the general questionnaire and to select the statement that they agreed with the most. Once they had ticked the pertinent statement, participants were then instructed to turn to the set of paired comparisons that had the same label as the statements they had ticked. Participants were then instructed to tick the statement in each pair that they agreed with the most and to respond to all pairs in their set.

Once they had finished their appropriate paired comparisons for the general questionnaire, a message at the bottom of the page prompted participants to turn to another page where the set of statements of the time limit questionnaire was listed. They
completed this questionnaire in exactly the same manner as the general questionnaire and were prompted upon finishing to turn to the impulsivity questionnaire. Once participants had finished this questionnaire, they were prompted that they were finished. The researcher then quickly checked their responses and then they were free to leave.

**Results**

**Inspection of paired comparison proportions matrices**

It was hypothesised that the revised statements in each questionnaire would display a unilateral ordering as predicted by Michell’s (1998) theory of the ordinal determinable. This hypothesis was strongly supported by visual inspection of the special proportion matrices devised for unilateral paired comparison tasks. The findings, however, of the probabilistic models were mixed.

The paired comparison matrices and the paired comparison proportions matrices differed to those used in the previous studies. Paired comparisons completed after the selection either statement A or F as the participant’s preferred statement used the same 6 x 6 matrix as per the previous studies. Paired comparisons completed after the selection of either statement B, C, D or E as the participant’s preferred statement each used a unique matrix.

Thirty – two participants chose statement A as their preferred statement for the general questionnaire. Please refer to Figure 9. Twenty – six gave transitive unilateral orderings. The other 6 gave mildly intransitive unilateral orderings.
Thirty chose statement A for the time limit and impulsivity questionnaires. Please refer to Figure 10. Twenty – one gave transitive unilateral orderings for the time limit questionnaire. Of the other 9 participants, 8 gave mildly intransitive orderings. One gave an intransitive ordering as two paired comparison tasks were reversed.

Please refer to Figure 11. Twenty – two participants gave transitive unilateral orderings for the impulsivity questionnaire. The other 8 participants gave mildly intransitive orderings.
<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>*</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>*</td>
<td>.90</td>
<td>.93</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>*</td>
<td>.97</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>*</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>*</td>
<td>.97</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

Figure 11: Proportions matrix for participants who selected statement A as their preferred statement in the impulsivity questionnaire (n = 30).

Please refer to Figures 12 and 13. Four participants selected statement B as their preferred statement for the general and time limit questionnaires. Only one participant gave an intransitive ordering for the general questionnaire (B/C paired comparison task reversed). All four participants gave transitive unilateral orderings for the time limit questionnaire.

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>*</td>
<td>.75</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>*</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>*</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

Figure 12: Proportions matrix for participants who selected statement B as their preferred statement for the general questionnaire (n = 4).
Six chose statement B for the impulsivity questionnaire. Please refer to Figure 14. For paired comparison tasks B/C, B/D and C/D, one participant gave reverse orderings.

One subject selected statement E for all 3 questionnaires and gave a mildly intransitive unilateral ordering for the general questionnaire. One subject selected statement C for the general and time limit questionnaires and gave unilateral orderings for them, but failed to complete the impulsivity questionnaire. One other participant chose statement C for the time limit questionnaire and gave a unilateral ordering.

Two participants failed to follow instructions and their responses to all 3 questionnaires were excluded from analysis. One participant failed to complete all the pertinent paired comparison tasks for the general and time limit questionnaires and thus the responses to them were excluded from analysis. One participant made this mistake for the time limit questionnaire and another did for the impulsivity questionnaire and thus their responses to these questionnaires were excluded from analysis.
Stronger evidence of the inferiority of the rating scale procedure compared to the paired comparison procedure was found. For the general questionnaire, 34 participants gave more than one statement pair a tied rating. Seven tied one statement pair and none gave untied ratings. Thirty-four made more than one tied rating in the time limit questionnaire with 5 making one tied rating. Two participants gave untied ratings but gave intransitive preference orders of ABCDEF and EFDBCA. But both participants gave transitive unilateral orderings in the paired comparison task of ABCDEF and EFDCBA, respectively.

Interestingly, one participant gave a transitive preference order of ABCDEF in the ratings task and a transitive unilateral preference order of BACDEF in the paired comparison task of the impulsivity questionnaire. Three other participants gave in the ratings task the intransitive preference orders of ADCBEF, ABCEDF and ACBEDF; but in the paired comparison tasks the transitive unilateral preference orders of BACDEF, ABCDEF and BACDEF, respectively. Thirty participants gave more than one statement pair a tied rating with 7 making one tied rating.

The above results strongly suggest that the rating scale procedure generates inaccurate data which must be interpreted cautiously. The paired comparison procedure is very accurate and hence can be used to verify or disqualify rating scale data if both procedures are used.

**Paired comparison probabilistic analyses**

The interpretations made thus far must be qualified more rigorously than by visual inspection. To this end, analyses of the paired comparison data were conducted using the models displayed in Eqs 1 and 2. The results of the hyperbolic cosine unfolding model for paired comparisons are presented in Tables 1 - 6.

<p>| Table 1. HCM model for the paired comparison data of the general questionnaire |
|---------------------------------|----------------|----------------|</p>
<table>
<thead>
<tr>
<th>Statement</th>
<th>Location ($\delta_i$)</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4.077</td>
<td>.264</td>
</tr>
<tr>
<td>B</td>
<td>5.075</td>
<td>.252</td>
</tr>
<tr>
<td>C</td>
<td>6.440</td>
<td>.275</td>
</tr>
<tr>
<td>D</td>
<td>-3.317</td>
<td>.313</td>
</tr>
<tr>
<td>E</td>
<td>-4.944</td>
<td>.322</td>
</tr>
<tr>
<td>F</td>
<td>-7.330</td>
<td>.460</td>
</tr>
</tbody>
</table>
Table 2: Chi-square test of paired comparison fit and overall model fit of data in Table 1.

<table>
<thead>
<tr>
<th>Statement</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>.00</td>
<td>.07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>.47</td>
<td>.10</td>
<td>.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>4.85*</td>
<td>.57</td>
<td>.17</td>
<td>.03</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>35.03**</td>
<td>7.43**</td>
<td>.77</td>
<td>.18</td>
<td>.00</td>
</tr>
</tbody>
</table>

Total overall fit $\chi^2_{[10]} = 49.75^{**}$

* $p < .05$, ** $p < .01$

Table 3: HCM model for the paired comparison data of the time limit questionnaire

<table>
<thead>
<tr>
<th>Statement</th>
<th>$\delta_i$</th>
<th>Location</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.619</td>
<td></td>
<td>.291</td>
</tr>
<tr>
<td>B</td>
<td>5.010</td>
<td></td>
<td>.249</td>
</tr>
<tr>
<td>C</td>
<td>6.535</td>
<td></td>
<td>.290</td>
</tr>
<tr>
<td>D</td>
<td>-3.527</td>
<td></td>
<td>.291</td>
</tr>
<tr>
<td>E</td>
<td>-4.888</td>
<td></td>
<td>.273</td>
</tr>
<tr>
<td>F</td>
<td>-6.749</td>
<td></td>
<td>.381</td>
</tr>
</tbody>
</table>

Table 4: Chi-square test of paired comparison fit and overall model fit of data in Table 3.

<table>
<thead>
<tr>
<th>Statement</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>.76</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>.85</td>
<td>.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>.01</td>
<td>.22</td>
<td>1.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>1.34</td>
<td>.02</td>
<td>.49</td>
<td>.92</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>5.94</td>
<td>1.24</td>
<td>.08</td>
<td>4.94</td>
<td>.31</td>
</tr>
</tbody>
</table>

Total overall fit $\chi^2_{[18]} = 18.77$

Table 5: HCM model for the paired comparison data of the impulsivity questionnaire

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location ($\delta_i$)</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4.095</td>
<td>.275</td>
</tr>
<tr>
<td>B</td>
<td>5.495</td>
<td>.230</td>
</tr>
<tr>
<td>C</td>
<td>6.450</td>
<td>.259</td>
</tr>
<tr>
<td>D</td>
<td>-2.711</td>
<td>.356</td>
</tr>
<tr>
<td>E</td>
<td>-5.438</td>
<td>.364</td>
</tr>
<tr>
<td>F</td>
<td>-7.889</td>
<td>.523</td>
</tr>
</tbody>
</table>
Table 6: Chi-square test of paired comparison fit and overall model fit of data in Table 5.

<table>
<thead>
<tr>
<th>Statement</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>.01</td>
<td>.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>.38</td>
<td>.34</td>
<td>.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>7.67**</td>
<td>.86</td>
<td>.28</td>
<td>.02</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>10.01**</td>
<td>10.93**</td>
<td>4.17*</td>
<td>.01</td>
<td>.01</td>
</tr>
</tbody>
</table>

Total overall fit $\chi^2_{(5)} = 34.76**$

* $p < .05$, ** $p < .01$

Rating scale probabilistic analyses

Table 7. Locations and latitude of acceptance parameter values of the SSLM (general version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.788 (.103)</td>
<td>.187 (.003)</td>
</tr>
<tr>
<td>B</td>
<td>.488 (.086)</td>
<td>.081 (.001)</td>
</tr>
<tr>
<td>C</td>
<td>-.148 (.071)</td>
<td>.043 (.001)</td>
</tr>
<tr>
<td>D</td>
<td>-.093 (.070)</td>
<td>.043 (.001)</td>
</tr>
<tr>
<td>E</td>
<td>-.498 (.087)</td>
<td>.045 (.001)</td>
</tr>
<tr>
<td>F</td>
<td>-.537 (.090)</td>
<td>.043 (.001)</td>
</tr>
</tbody>
</table>

Table 8 Locations and latitude of acceptance parameter values of the HCM (general version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.609 (.087)</td>
<td>.405 (.019)</td>
</tr>
<tr>
<td>B</td>
<td>.762 (.064)</td>
<td>.183 (.010)</td>
</tr>
<tr>
<td>C</td>
<td>-.245 (.064)</td>
<td>.095 (.012)</td>
</tr>
<tr>
<td>D</td>
<td>-.223 (.062)</td>
<td>.111 (.011)</td>
</tr>
<tr>
<td>E</td>
<td>-1.112 (.082)</td>
<td>.134 (.013)</td>
</tr>
<tr>
<td>F</td>
<td>-.790 (.091)</td>
<td>.027 (.040)</td>
</tr>
</tbody>
</table>

Table 9. Locations and latitude of acceptance parameter values of the PARELLA model (general version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.941 (.106)</td>
<td>.839 (.061)</td>
</tr>
<tr>
<td>B</td>
<td>3.394 (.073)</td>
<td>.500 (.031)</td>
</tr>
<tr>
<td>C</td>
<td>-1.106 (.124)</td>
<td>.337 (.022)</td>
</tr>
<tr>
<td>D</td>
<td>-2.719 (.234)</td>
<td>.594 (.035)</td>
</tr>
<tr>
<td>E</td>
<td>-1.070 (.116)</td>
<td>.231 (.019)</td>
</tr>
<tr>
<td>F</td>
<td>-1.441 (.155)</td>
<td>.211 (.020)</td>
</tr>
</tbody>
</table>
### Table 10. Locations and latitude of acceptance parameter values of the SSLM (time involvement version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.748 (.089)</td>
<td>.153 (.002)</td>
</tr>
<tr>
<td>B</td>
<td>.293 (.071)</td>
<td>.116 (.001)</td>
</tr>
<tr>
<td>C</td>
<td>.140 (.078)</td>
<td>.034 (.001)</td>
</tr>
<tr>
<td>D</td>
<td>-.412 (.081)</td>
<td>.041 (.001)</td>
</tr>
<tr>
<td>E</td>
<td>-.282 (.077)</td>
<td>.036 (.001)</td>
</tr>
<tr>
<td>F</td>
<td>-.486 (.088)</td>
<td>.034 (.001)</td>
</tr>
</tbody>
</table>

### Table 11. Locations and latitude of acceptance parameter values of the HCM (time involvement version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.425 (.074)</td>
<td>.338 (.015)</td>
</tr>
<tr>
<td>B</td>
<td>.421 (.065)</td>
<td>.256 (.011)</td>
</tr>
<tr>
<td>C</td>
<td>.083 (.061)</td>
<td>.106 (.011)</td>
</tr>
<tr>
<td>D</td>
<td>-.613 (.075)</td>
<td>.044 (.026)</td>
</tr>
<tr>
<td>E</td>
<td>-.468 (.068)</td>
<td>.065 (.017)</td>
</tr>
<tr>
<td>F</td>
<td>-.848 (.082)</td>
<td>.069 (.019)</td>
</tr>
</tbody>
</table>

### Table 12. Locations and latitude of acceptance parameter values of the PARELLA model (time involvement version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.563 (.071)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>B</td>
<td>2.054 (.065)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>C</td>
<td>2.425 (.069)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>D</td>
<td>-2.661 (.242)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>E</td>
<td>-2.021 (.176)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>F</td>
<td>-2.361 (.209)</td>
<td>.400 (.000)</td>
</tr>
</tbody>
</table>

### Table 13. Locations and latitude of acceptance parameter values of the SSLM (impulse version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.988 (.099)</td>
<td>.293 (.006)</td>
</tr>
<tr>
<td>B</td>
<td>.146 (.069)</td>
<td>.086 (.001)</td>
</tr>
<tr>
<td>C</td>
<td>-.098 (.067)</td>
<td>.086 (.001)</td>
</tr>
<tr>
<td>D</td>
<td>-.226 (.078)</td>
<td>.038 (.001)</td>
</tr>
<tr>
<td>E</td>
<td>-.288 (.078)</td>
<td>.040 (.001)</td>
</tr>
<tr>
<td>F</td>
<td>-.522 (.095)</td>
<td>.018 (.001)</td>
</tr>
</tbody>
</table>
### Table 14. Locations and latitude of acceptance parameter values of the HCM (impulses version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.779 (.098)</td>
<td>.659 (.031)</td>
</tr>
<tr>
<td>B</td>
<td>.316 (.063)</td>
<td>.144 (.010)</td>
</tr>
<tr>
<td>C</td>
<td>-.168 (.063)</td>
<td>.140 (.010)</td>
</tr>
<tr>
<td>D</td>
<td>-.440 (.069)</td>
<td>.080 (.013)</td>
</tr>
<tr>
<td>E</td>
<td>-.577 (.071)</td>
<td>.084 (.013)</td>
</tr>
<tr>
<td>F</td>
<td>-.910 (.095)</td>
<td>.013 (.105)</td>
</tr>
</tbody>
</table>

### Table 15. Locations and latitude of acceptance parameter values of the PARELLA model (impulses version)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Location (SE)</th>
<th>Latitude of acceptance (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.594 (.038)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>B</td>
<td>4.549 (.111)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>C</td>
<td>-.214 (.104)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>D</td>
<td>-.1823 (.188)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>E</td>
<td>-.2013 (.206)</td>
<td>.400 (.000)</td>
</tr>
<tr>
<td>F</td>
<td>-.3093 (.332)</td>
<td>.400 (.000)</td>
</tr>
</tbody>
</table>

The results of the probabilistic analyses are mixed. For all three questionnaires, the paired comparison HCM ordered the statements differently to that predicted by the ordinal determinable. The models place the statements in the order C, B, A, D, E, F. Yet the fit of the models to the data appears sound. The rating scale unfolding models do not accord with the paired comparison models. Out of these models, the PARELLA function produced the greatest disordering of statements across all three questionnaires. For the general questionnaire, the SSLM and HCM models produced the orderings A, B, D, C, E, F and A, B, D, C, F, E, respectively. For the time limit questionnaire, the SSLM and HCM models produced the ordering A, B, C, E, D, F. The HCM and SSLM models produced the correct statement orderings with the PARELLA model producing B, A, C, D, E, F.

**Discussion**

The incongruous nature of the results of the probabilistic analyses suggest that they be interpreted cautiously. They are at best inconclusive. One serious problem in their application to the data of the present study was the relative lack of error in the data as indicated in Figs. 11 - 14. As the models are probabilistic and as such assume certain features of errors, the lack of error may have violated these assumptions and thus led to the misorderings of the statements.
The distinct lack of error in the present study, and the large discrepancy between the results of this study and the last, suggests that one conclusion of the previous study was correct. The unidimensional paired comparison methodology used in the previous studies strongly appears to be too difficult a task for the participants used in all three studies. First year psychology students have typically just matriculated from high school and have presumably had very little experience of completing questionnaires or participating in psychological studies. Secondly, the results of the present study strongly suggest that there is a strong expectation that one is going to be asked about one's own behaviour when approached to complete a questionnaire. It can be safely concluded then that if a questionnaire study utilises either Coombs' (1950,1964) theory or Michell's (1998) theory in statement construction, paired comparison methodology must be made as simple as possible for participants to accurately complete questionnaires. The easiest method appears to be unilateral or bilateral preferencepaired comparison procedures, depending on whether the researcher is testing unidimensionality or the unfolding condition, the latter of course assuming that the statements are indeed unidimensionally ordered.

The huge discrepancies in the data generated by the rating scale and paired comparison procedures point strongly to the superiority of the latter over the former. This is no doubt due to the fact that the paired comparison procedure does not allow for tied ratings. Participants responses are less restricted in ratings tasks hence the error discovered both in this and the previous study. That there was no improvement in this study in the ratings tasks despite the alteration of the semantic categories strongly supports this conclusion.

The results of the present study, however, may have been influenced by other changes made in the procedure. Unlike the previous studies, it was difficult for participants to see other participants' responses. This may have prevented their responses being distorted from looking at others' responses. The researcher at the very beginning of the study stressed how important it was to participants to complete the questionnaires as carefully as they could. This mild coaxing of participants may have prevented most of them from making careless or ad – hoc responses. Nevertheless, it seems tenuous to argue that these two factors account for the large discrepancy in the results between the present study and the previous ones.

The results of the present study, however, may not have been so strong had the original sets of statements used in the first pilot study been used in the present study. The
moderate improvement between the first and second pilot studies suggests that the original statements were indeed ambiguous and relatively poorly constructed. This improvement is notable as both studies used the difficult, unidimensional paired comparison methodology. It seems likely that if the original statements were used in the present study the results would have been contaminated by error. This could of course be tested but it was not the aim of the three studies to examine the efficacy of the various paired comparison methodologies.

The small amount of error in the present study is easily identified. Most of the error stemmed from participants giving mildly intransitive orderings. That is, they made one mistake in reversing one paired comparison task. This may have been due to a minor lapse in participants’ concentration. Paired comparison methodologies are inherently taxing of participants’ motivational and attentional resources. Given that most participants chose statement A as their preferred statement, most participants had to complete 45 paired comparison tasks. This is a fair number and could have tested the participants’ concentration skills. This can be controlled to a certain extent by reducing the number of paired comparison procedures. But this would have required the omission of one or two of the questionnaires as the use of the bilateral paired comparison procedure was not possible as unidimensionality of the statements had yet to be demonstrated.

The participants who did not follow instructions may have done so out of apathy or confusion; participants experiencing the latter not making use of asking the researcher to clarify what was required. This is not easily controlled and the best course of action (which was followed in this study) is to omit the responses of these people in final analyses. There were only 2 participants in the present study who gave completely illegible responses so this disposal of data could be done quite safely.

In conclusion, the empirical hypothesis stated at the beginning of the study was confirmed. The statements within each questionnaire are ordered unidimensionally according to Michell’s (1998) theory of the ordinal determinable. What remains, however, is a test of the questionnaires’ reliability and a bilateral paired comparison test of participants’ preferences. This done, the important condition of unfolding could then be tested and if passed, the attribute of loss of control could be tested by the theory of simultaneous, additive conjoint measurement (Luce & Tukey, 1964) for the presence of additive structure. These tests will be the aims of any following study.
Appendix 4: Rating Scale Item Expectation Curves for the statements of the Subjective Control scale of general control over gambling.

Figure 1. SSSLM item expected value curve of Statement A.

Figure 2. SSSLM item expected value curve of Statement A (retest phase).

Expected Value  Item 3: Loc= 0.37, Unii= 0.15, Label= Item03.

Expected Value  Item 3: Loc= 0.76, Unii= 0.13, Label= Item03.
Figure 3. SSLM item expected value curve of Statement B.

Figure 4. SSLM item expected value curve of Statement B (retest phase).
Figure 5. SSLM item expected value curve of Statement C.

Figure 6. SSLM item expected value curve of Statement C (retest phase).
Figure 7. SSSLM item expected value curve of Statement D.

Figure 8. SSSLM item expected value curve of Statement D (retest phase).
Figure 9. SSMART item expected value curve of Statement E.

Figure 10. SSMART item expected value curve of Statement E (retest phase).
Figure 11. SSSLM item expected value curve of Statement F.

Figure 12. SSSLM item expected value curve of Statement F (retest phase).
Appendix 5: Rating Scale Item Expectation Curves for the statements of the Subjective Control scale of control over time spent gambling.

Figure 13. HCM item expected value curve of Statement A.

Figure 14. HCM item expected value curve of Statement A (retest phase).
Figure 15. HCM item expected value curve for Statement B.

Figure 16. HCM item expected value curve of Statement B (retest phase).
Figure 17. HCM item expected value curve of Statement C.

Figure 18. HCM item expected value curve of Statement C (retest phase).
Figure 19. HCM item expected value curve of Statement D.

Figure 20. HCM item expected value curve of Statement D (retest phase).
Figure 21. HCM item expected value curve of Statement E.

Figure 22. HCM item expected value curve of Statement E (retest phase).
Figure 23. HCM item expected value curve of Statement F.

Figure 24. HCM item expected value curve of Statement F (retest phase).
Figure 25. PARELLA item expected value curve of Statement A.

Figure 26. PARELLA item expected value curve of Statement A (retest phase).
Figure 27. PARELLA item expected value curve of Statement B.

Figure 28. PARELLA item expected value curve of Statement B (retest phase).
Figure 29. PARELLA item expected value curve of Statement C.

Figure 30. PARELLA item expected value curve for Statement C (retest phase).
Figure 31. PARELLA item expected value curve of Statement D.

Figure 32. PARELLA item expected value curve of Statement D (retest phase).
Figure 33. PARELLA item expected value curve of Statement E.

Figure 34. PARELLA item expected value curve of Statement E (retest phase).
Figure 35. PARELLA item expected value curve for Statement F.

Figure 36. PARELLA item expected value curve of Statement F (retest phase).
Appendix 5: Rating Scale Item Expectation Curves for the statements of the Subjective Control scale of control over time spent gambling.

Figure 1. Item expected score curve for Statement A according to the SSLM.

Figure 2. Item expected value curve for Statement A (retest phase) according to the SSLM.
Figure 3. Item expected value curve for Statement B according to the SLLM.

Figure 4. Item expected value curve for Statement B (retest phase) according to the SLLM.
Figure 5. Item expected value curve for Statement C according to the SSLM.

Figure 6. Item expected value curve for Statement C (retest phase) according to the SSLM.
Figure 7. Item expected value curve for Statement D according to the SSLM.

Figure 8. Item expected value curve for Statement D (retest phase) according to the SSLM.
Figure 9. Item expected value curve for Statement E according to the SSLM.

Figure 10. Item expected value curve for Statement E (retest phase) according to the SSLM.
Figure 11. Item expected value curve for Statement F according to the SSLM.

Figure 12. Item expected value curve for Statement F (retest phase) according to the SSLM.
Figure 13. Item expected value curve for Statement A according to the HCM.

Figure 14. Item expected value curve for Statement A (retest phase) according to the HCM.
Figure 15. Item expected value curve for Statement B according to the HCM.

Figure 16. Item expected value curve for Statement B (retest phase) according to the HCM.
Figure 17. Item expected value curve for Statement C according to the HCM.

Figure 18. Item expected value curve for Statement C (retest phase) according to the HCM.
Figure 19. Item expected value curve for Statement D according to the HCM.

Figure 20. Item expected value curve for Statement D (retest phase) according to the HCM.
Figure 21. Item expected value curve for Statement E according to the HCM.

Figure 22. Item expected score curve for Statement E (retest phase) according to the HCM.
Figure 23. Item expected value curve for Statement F according to the HCM.

Figure 24. Item expected value curve for Statement F (retest phase) according to the HCM.
Appendix 6: Rating Scale Item Expectation Curves for the statements of the Subjective Control scale of control over urges to gamble.

Figure 1. Item expected value curve for Statement A according to the SSM.

Figure 2. Item expected value curve for Statement A (retest) according to the SSM.
Figure 3. Item expected value curve for Statement B according to the SSSL.

Figure 4. Item expected value curve for Statement B (retest phase) according to the SSSL.
Figure 5. Item expected value curve for Statement C according to the SSSLM.

Figure 6. Item expected value curve for Statement C (retest phase) according to the SSSLM.
Figure 7. Item expected value curve for Statement D according to the SSSLM.

Figure 8. Item expected value curve for Statement D (retest phase) according to the SSSLM.
Figure 9. Item expected value curve for Statement E according to the SLM.

Figure 10. Item expected value curve for Statement E (retest phase) according to the SLM.
Figure 11. Item expected value curve for Statement F according to the SLLM.

Figure 12. Item expected value curve for Statement F (retest phase) according to the SLLM.
Figure 13. Item expected value curve for Statement A according to the HCM.

Figure 14. HCM item expected value curve for Statement A (retest phase).
Figure 15. HCM item expected value curve for Statement B.

Figure 16. HCM item expected value curve for Statement B (retest phase).
Figure 17. HCM Item expected value curve for Statement C.

Figure 18. HCM item expected value curve for Statement C (retest phase).
Figure 19. HCM item expected value curve for Statement D.

Figure 20. HCM item expected value curve for Statement D (retest phase).
Figure 21. HCM item expected value curve for Statement E.

Figure 22. HCM item expected value curve for Statement E (retest phase).
Figure 23. HCM expected value curve for Statement F.

Figure 24. HCM expected value curve for Statement F (retest phase).
Appendix 7. Statement maps and person distributions of the rating scale models.

Figure 1. SSLM statement map for the general questionnaire.

Figure 2. SSLM person distribution for the general questionnaire.
Figure 3. SSLM statement map for the general questionnaire (retest phase).

Figure 4. SSLM person distribution for the general questionnaire (retest phase).
Figure 5. HCM statement map for the general questionnaire.

Figure 6. HCM person distribution for the general questionnaire.
Figure 7. HCM statement map for the general questionnaire (retest phase).

Figure 8. HCM person distribution for the general questionnaire (retest phase).
Figure 9. PARELLA statement map for the general questionnaire.

Figure 10. PARELLA person distribution for the general questionnaire.
Figure 11. PARELLA statement map for the general questionnaire (retest phase).

Figure 12. PARELLA person distribution for the general questionnaire (retest phase).
Figure 13. SSLM statement map for the time limit questionnaire.

Figure 14. SSLM person distribution for the time limit questionnaire.
Figure 15. SSLM statement map for the time limit questionnaire (retest phase).

Figure 16. SSLM person distribution for the time limit questionnaire (retest phase).
Figure 17. HCM statement map for the time limit questionnaire.

Figure 18. HCM person distribution for the time limit questionnaire.
Figure 19. HCM statement map for the time limit questionnaire (retest phase).

Figure 20. HCM person distribution for the time limit questionnaire (retest phase).
Figure 21. SSLM statement map for the impulsivity questionnaire.

Figure 22. SSLM person distribution for the impulsivity questionnaire.
Figure 23. SSLM statement map for the impulsivity questionnaire (retest phase).

Figure 24. SSLM person distribution for the impulsivity questionnaire (retest phase).
Figure 25. HCM statement map for the impulsivity questionnaire.

Figure 26. HCM person distribution for the impulsivity questionnaire.
Figure 27. HCM statement map for the impulsivity questionnaire (retest phase).

Figure 28. HCM person distribution for the impulsivity questionnaire (retest phase).
Appendix 8: Item probability graphs for the HCM paired comparison model for the general questionnaire.

Figure 1: Paired choice graph of Statement A against Statement B.

Figure 2: Paired choice graph of Statement A against Statement B (retest).

Figure 3: Paired choice graph of Statement A against Statement C.
Figure 4: Paired choice graph of Statement A against Statement C (retest).

Figure 5: Paired choice graph of Statement A against Statement D.

Figure 6: Paired choice graph of Statement A against Statement D (retest).
Figure 7: Paired choice graph of Statement A against Statement E.

Figure 8: Paired choice graph of Statement A against Statement E (retest).

Figure 9: Paired choice graph of Statement A against Statement F.
Figure 10. Paired choice graph of Statement A against Statement F (retest).

Figure 11. Paired choice graph of Statement B against Statement C.

Figure 12. Paired choice graph of Statement B against Statement C (retest).
Figure 13. Paired choice graph of Statement B against Statement D.

Figure 14. Paired choice graph of Statement B against Statement D (retest)

Figure 15. Paired choice graph of Statement B against Statement E.
Figure 16. Paired choice graph of Statement B against Statement E (retest)

Figure 17. Paired choice graph of Statement B against Statement F.

Figure 18. Paired choice graph of Statement B against Statement F (retest)
Figure 19. Paired choice graph of Statement C against Statement D.

Figure 20. Paired choice graph of Statement C against Statement D (retest).

Figure 21. Paired choice graph of Statement C against Statement E.
Figure 22. Paired choice graph of Statement C against Statement E (retest)

Figure 23. Paired choice graph of Statement C against Statement F.

Figure 24. Paired choice graph of Statement C against Statement F (retest)
Figure 25. Paired choice graph of Statement D against Statement E.

Figure 26. Paired choice graph of Statement D against Statement E (retest)

Figure 27. Paired choice graph of Statement D against Statement F.
Figure 28. Paired choice graph of Statement D against Statement F (retest).

Figure 29. Paired choice graph of Statement E against Statement F.

Figure 30. Paired choice graph of Statement E against Statement F (retest).
Appendix 9: Item probability graphs for the HCM paired comparison model for the time limit questionnaire.

Figure 1. Paired choice graph of Statement A against Statement B.

Figure 2. Paired choice graph of Statement A against Statement B (retest phase).

Figure 3. Paired choice graph of Statement A against Statement C.
Figure 4. Paired choice graph of Statement A against Statement C (retest phase).

Figure 5. Paired choice graph of Statement A against Statement D.

Figure 6. Paired choice graph of Statement A against Statement D (retest phase).
Figure 7. Paired choice graph of Statement A against Statement E.

Figure 8. Paired choice graph of Statement A against Statement E (retest)

Figure 9. Paired choice graph of Statement A against Statement F.
Figure 10. Paired choice graph of Statement A against Statement F (retest phase).

Figure 11. Paired choice graph of Statement B against Statement C.

Figure 12. Paired choice graph of Statement B against Statement C (retest phase).
Figure 13. Paired choice graph of Statement B against Statement D.

Figure 14. Paired choice graph of Statement B against Statement D (retest phase).

Figure 15. Paired choice graph of Statement B against Statement E.
Figure 16. Paired choice graph of Statement B against Statement E (retest phase).

Figure 17. Paired choice graph of Statement B against Statement F.

Figure 18. Paired choice graph of Statement B against Statement F (retest).
Figure 19. Paired choice graph of Statement C against Statement D.

Figure 20. Paired choice graph of Statement C against Statement D (retest phase).

Figure 21. Paired choice graph of Statement C against Statement E.
Figure 22. Paired choice graph of Statement C against Statement E (retest phase).

Figure 23. Paired choice graph of Statement C against Statement F.

Figure 24. Paired choice graph of Statement C against Statement F (retest phase).
Figure 25. Paired choice graph of Statement D against Statement E.

Figure 26. Paired choice graph of Statement D against Statement E (retest).

Figure 27. Paired choice graph of Statement D against Statement F.
Figure 28. Paired choice graph of Statement D against Statement F (retest phase).

Figure 29. Paired choice graph of Statement E against Statement F.

Figure 30. Paired choice graph of Statement E against Statement F (retest phase).
Appendix 10: Item probability graphs for the HCM paired comparison model for the impulsivity questionnaire.

Figure 1. Paired choice graph of Statement A against Statement B.

Figure 2. Paired choice graph of Statement A against Statement B (retest phase).

Figure 3. Paired choice graph of Statement A against Statement C.
Figure 4. Paired choice graph of Statement A against Statement C (retest phase).

Figure 5. Paired choice graph of Statement A against Statement D.

Figure 6. Paired choice graph of Statement A against Statement D (retest phase).
Figure 7. Paired choice graph of Statement A against Statement E.

Figure 8. Paired choice graph of Statement A against Statement E (retest phase).

Figure 9. Paired choice graph of Statement A against Statement F.
Figure 10. Paired choice graph of Statement A against Statement F (retest phase).

Figure 11. Paired choice graph of Statement B against Statement C.

Figure 12. Paired choice graph of Statement B against Statement C (retest phase).
Figure 13. Paired choice graph of Statement B against Statement D.

Figure 14. Paired choice graph of Statement B against Statement D (retest phase).

Figure 15. Paired choice graph of Statement B against Statement E.
Figure 16. Paired comparison graph of Statement B against Statement E (retest).

Figure 17. Paired comparison graph of Statement B against Statement F.

Figure 18. Paired comparison graph of Statement B against Statement F (retest phase).
Figure 19. Paired comparison graph of Statement C against Statement D.

Figure 20. Paired comparison graph of Statement C against Statement D (retest phase).

Figure 21. Paired comparison graph of Statement C against Statement E.
Figure 22. Paired comparison graph of Statement C against Statement E (retest phase).

Figure 23. Paired choice graph of Statement C against Statement F.

Figure 24. Paired choice graph of Statement C against Statement F (retest phase).
Figure 25. Paired choice graph of Statement D against Statement E.

Figure 26. Paired choice graph of Statement D against Statement E (retest phase).

Figure 27. Paired choice graph of Statement D against Statement F.
Figure 28. Paired choice graph of Statement D against Statement F (retest phase).

Figure 29. Paired choice graph of Statement E against Statement F.

Figure 30. Paired choice graph of Statement E against Statement F (retest phase).
Appendix 11: Person distributions for the HCM unfolding model for pairwise preferences.

Figure 1. Person distribution and item locations for the general version of the Subjective Control scales.

Figure 2. Person distribution and item locations for the general version of the Subjective Control scales (retest phase).

Figure 3. Person distribution and item locations for the impulses to gamble version of the Subjective Control scales.
Figure 4. Person distribution and item locations for the impulses to gamble version of the Subjective Control scales (retest phase).

Figure 5. Person distribution and item locations for the time involvement version of the Subjective Control scales.

Figure 6. Person distribution and item locations for the time involvement version of the Subjective Control scales (retest phase).
Appendix 12: Scatter plots of the transformed Goode’s algorithm and SHCM pairwise preference statement values.

Figure 1. Scatter plot of the transformed Goode’s algorithm and HCM pairwise preference statement values for the general version of the Subjective Control Scales.

Figure 2. Scatter plot of the transformed Goode’s algorithm and HCM pairwise preference statement values for the general version of the Subjective Control Scales (retest phase).
Figure 3. Scatter plot of the transformed Goode's algorithm and HCM pairwise preference statement values for the impulses to gamble version of the Subjective Control Scales.

Figure 4. Scatter plot of the transformed Goode's algorithm and SHCM pairwise preference statement values for the impulses to gamble version of the Subjective Control Scales (retest phase).
Figure 5: Scatter plot of the transformed Goode's algorithm and SHCM pairwise preference statement values for the time involvement version of the Subjective Control Scales. The transformed Goode's solution pertains to the right hand branch of the dominant / scale path found for this version in Chapter 5.

Figure 6: Scatter plot of the transformed Goode's algorithm and HCM pairwise preference statement values for the time involvement version of the Subjective Control Scales (retest phase). The transformed Goode's solution pertains to the right hand branch of the dominant / scale path found for this version in Chapter 5.
Figure 7: Scatter plot of the transformed Goode's algorithm and HCM pairwise preference statement values for the time involvement version of the Subjective Control Scales. The transformed Goode's solution pertains to the left hand branch of the dominant / scale path found for this version in Chapter 5.

Figure 8: Scatter plot of the transformed Goode's algorithm and HCM pairwise preference statement values for the time involvement version of the Subjective Control Scales. The transformed Goode's solution pertains to the left hand branch of the dominant / scale path found for this version in Chapter 5.

Appendix 12b: Line fitting of log transformed SHCM statement locations.
Figure 1. Fitting of line (with constants) to the natural logarithm of the general test transformed logit scale.

Figure 2. Fitting of line (with constants) to the natural logarithm of the general test transformed logit scale (retest condition).
Figure 3. Fitting of line (with constants) to the natural logarithm of the impulses transformed logit scale.

Figure 4. Fitting of line (with constants) to the natural logarithm of the impulses transformed logit scale (retest condition).
Figure 5. Fitting of line (with constants) to the natural logarithm of the time limit transformed logit scale.

Figure 6. Fitting of line (with constants) to the natural logarithm of the time limit transformed logit scale (retest condition).
Figure 7. Fitting of line (with constants) to the natural logarithm of the time limit transformed logit scale.

Figure 8. Fitting of line (with constants) to the natural logarithm of the time limit transformed logit scale (retest condition).
Appendix 13: Scatter plots of the transformed Goode’s algorithm and GHCM rating scale statement values.

Figure 1. Scatter plot of the transformed Goode’s algorithm and GHCM rating scale statement values for the general version of the Subjective Control Scales.

Figure 2. Scatter plot of the transformed Goode’s algorithm and GHCM rating scale statement values for the general version of the Subjective Control Scales (retest condition).
Figure 3. Scatter plot of the transformed Goode’s algorithm and GHCM rating scale statement values for the impulses to gamble version of the Subjective Control Scales.

Figure 4. Scatter plot of the transformed Goode’s algorithm and GHCM rating scale statement values for the impulses to gamble version of the Subjective Control Scales (retest condition).
Figure 5: Scatter plot of the transformed Goode's algorithm and GHCM rating scale statement values for the time involvement version of the Subjective Control Scales. The transformed Goode's solution pertains to the right hand branch of the dominant / scale path found for this version in Chapter 5.

Figure 6: Scatter plot of the transformed Goode's algorithm and GHCM rating scale statement values for the time involvement version of the Subjective Control Scales (retest condition). The transformed Goode's solution pertains to the right hand branch of the dominant / scale path found for this version in Chapter 5.
Figure 7: Scatter plot of the transformed Goode's algorithm and GHCM rating scale statement values for the time involvement version of the Subjective Control Scales. The transformed Goode's solution pertains to the left hand branch of the dominant / scale path found for this version in Chapter 5.

Figure 8: Scatter plot of the transformed Goode's algorithm and GHCM rating scale statement values for the time involvement version of the Subjective Control Scales. The transformed Goode's solution pertains to the left hand branch of the dominant / scale path found for this version in Chapter 5.
Appendix 13a: Curve fitting of the scatterplots of Appendix 13.

General test transformed logit scale

Figure 1. Fitting of exponential curve (with constants) to the scatterplot depicted in Figure 1, Appendix 13.

General retest transformed logit scale

Figure 2. Fitting of exponential curve (with constants) to the scatterplot depicted in Figure 2, Appendix 13.
Figure 3. Fitting of exponential curve (with constants) to the scatterplot depicted in Figure 3, Appendix 13.

Figure 4. Fitting of exponential curve (with constants) to the scatterplot depicted in Figure 4, Appendix 13.
Figure 5. Fitting of exponential curve (with constants) to the scatterplot depicted in Figure 5, Appendix 13.

Figure 6. Fitting of exponential curve (with constants) to the scatterplot depicted in Figure 6, Appendix 13.
Figure 7. Fitting of exponential curve (with constants) to the scatterplot depicted in Figure 7, Appendix 13.

Figure 8. Fitting of exponential curve (with constants) to the scatterplot depicted in Figure 8, Appendix 13.
Appendix 13b: Line fitting of log transformed GHCM statement locations.

Natural log of general test transformed GHCM logit scale

Figure 1. Fitting of line (with constants) to the natural logarithm of the general test transformed logit scale.

Natural log of general retest GHCM transformed scales

Figure 2. Fitting of line (with constants) to the natural logarithm of the general transformed logit scale (retest condition).
Figure 3. Fitting of line (with constants) to the natural logarithm of the impulses transformed logit scale.

Figure 4. Fitting of line (with constants) to the natural logarithm of the impulses transformed logit scale (retest condition).
Figure 5. Fitting of line (with constants) to the natural logarithm of the time involvement transformed logit scale (retest condition).

Figure 6. Fitting of line (with constants) to the natural logarithm of the time involvement transformed logit scale (retest condition).
Natural log of time limit test GHCM transformed scales

Figure 7. Fitting of line (with constants) to the natural logarithm of the time involvement transformed logit scale.

Natural log of time limit retest GHCM transformed scales

Figure 8. Fitting of line (with constants) to the natural logarithm of the time involvement transformed logit scale (retest condition).
Appendix 14: Reference list of the random library survey of physics texts.


Appendix 15: Reference list of the random library survey of psychometric texts.


Appendix 16: First Subjective Control Scale questionnaire booklet administered to all participants

UWS, Macarthur: Department of Psychology

Participant No.: 

Age: 

Sex (M/F): 

What types of gambling do you play? (Tick any of the below):

Horses / Dogs: 

Card Machines: 

Poker Machines: 

Pools: 

Cards: 

TAB: 

Lotto: 

Bookmakers: 

Keno: 

Casino: 

Bingo: 

Lotteries: 

Of the above types of gambling, which is your favourite? 

425
How often do you gamble with your favourite form of gambling? (Answer one of the below):

Number of times per day: __________

Number of times per week: __________

Number of times per month: __________

Number of times per year: __________

In a typical session of gambling, how much do you usually spend (not including any winnings):

A$ ________ per typical session of gambling.
Task One Instructions

The following questionnaires are going to ask you about your gambling behaviour. It is very important that you do not make ad-hoc or careless responses in this entire exercise. Please make all of your responses very carefully.

What I want you to do are seven fairly easy tasks. The first task I will explain to you now. You will not commence the other tasks until all of you have finished the first task and the instructions for the other tasks have been read out.

For the first task, you will be presented with 3 questionnaires containing 6 statements each. Underneath each statement, there is a 11 point rating scale. For each statement decide how much you agree or disagree with it and indicate this by marking a point on the rating scale below it with a cross. Please note that “0” means that you totally disagree with the statement and “10” means that you totally agree with it.

There are no right or wrong answers. Your responses should be your own so ignore the responses made by anyone else. Please read each statement very carefully. Complete the questionnaires at your own pace, rating your agreement as accurately as you can.

Please do not write your name on any of the questionnaires. You may begin and I will be on hand to answer any questions you may have.
Set One

1. My gambling is impossible to control and it causes several, significant problems that are very distressing.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause problems yet I do think about cutting back from time to time.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. My gambling is very difficult but not impossible to control, even though it causes several problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Although I feel a need to control my gambling, it is easily controlled without conscious effort and it does not cause any problems.

6. Although my gambling is relatively difficult to control, it causes few but only minor problems.
Set Two

1. I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Set Three

1. I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause any problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. I sometimes experience strong impulses to gamble, but I can easily resist them without any conscious effort and my gambling does not cause any problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Task Two

The statements in the following group express levels of individual control over gambling behaviour. It is very important that you read through each of the statements carefully and then tick the statement nearest to your own level. That is, find the statement that you agree with most and then tick that statement. Tick one statement only. Your response should be your own, so please ignore the responses being made by anyone else.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.  

B. Although I feel a need to control my gambling, it is easily controlled without conscious effort and it does not cause any problems.  

C. I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause problems yet I do think about cutting back from time to time.  

D. Although my gambling is relatively difficult to control, it causes few but only minor problems.  

E. My gambling is very difficult but not impossible to control, even though it causes several problems.  

F. My gambling is impossible to control and it causes several, significant problems that are very distressing.  

Now the statements are presented to you in pairs. Your task is to judge for each pair of statements the one that you agree with the most. However, you do not need to do this for all of the following pairs of statements. Go straight to the set with the same label as the statement you ticked. That is, if you ticked Statement A, go to the set labelled A; if you ticked B, go to the set labelled B; and so on. Within each set make a judgment for each pair, ticking the statement in each pair that you agree with the most. Please tick one and only one statement in each pair. Please respond to all pairs in your set.

Immediately below each set of paired statements there is a prompt which will ask you to turn to a particular page. Please turn to that page and follow the instructions.
Set A

C. I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems although I do think about cutting back from time to time.

D. Although my gambling is relatively difficult to control, it causes few but only minor problems.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.

B. Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.

F. My gambling is impossible to control and it causes several, significant problems that are very distressing.

E. My gambling is very difficult but not impossible to control, even though it causes several problems.

C. I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort, but it does not cause any problems yet I do think about cutting back from time to time.

B. Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.

E. My gambling is very difficult but not impossible to control, even though it causes several problems.

D. Although my gambling is relatively difficult to control, it causes few but only minor problems.

Now please turn to page 16.
Set B

A. I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.

F. My gambling is impossible to control and it causes several, significant problems that are very distressing.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.

C. I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

D. Although my gambling is relatively difficult to control, it causes few but only minor problems.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.

E. My gambling is very difficult but not impossible to control, even though it causes several problems.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.

C. I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

B. Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.

Now please turn to page 16.
### Set C

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D.</td>
<td>Although my gambling is relatively difficult to control, it causes few but only minor problems.</td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B.</td>
<td>Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.</td>
</tr>
<tr>
<td>F.</td>
<td>My gambling is impossible to control and it causes several, significant problems that are very distressing.</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>E.</td>
<td>My gambling is very difficult but not impossible to control, even though it causes several problems.</td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B.</td>
<td>Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.</td>
</tr>
<tr>
<td>F.</td>
<td>My gambling is impossible to control and it causes several, significant problems that are very distressing.</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B.</td>
<td>Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.</td>
</tr>
<tr>
<td>E.</td>
<td>My gambling is very difficult but not impossible to control, even though it causes several problems.</td>
</tr>
</tbody>
</table>

Now please turn to page 16.
<table>
<thead>
<tr>
<th>A.</th>
<th>I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.</td>
<td>Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.</td>
</tr>
<tr>
<td>C.</td>
<td>I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.</td>
</tr>
<tr>
<td>D.</td>
<td>My gambling is impossible to control and it causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td>E.</td>
<td>My gambling is very difficult but not impossible to control, even though it causes several problems.</td>
</tr>
</tbody>
</table>

Now please turn to page 16.
Set E

A. I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.

F. My gambling is impossible to control and it causes several, significant problems that are very distressing.

B. Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.

F. My gambling is impossible to control and it causes several, significant problems that are very distressing.

C. I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

F. My gambling is impossible to control and it causes several, significant problems that are very distressing.

D. Although my gambling is relatively difficult to control, it causes few but only minor problems.

F. My gambling is impossible to control and it causes several, significant problems that are very distressing.

F. My gambling is impossible to control and it causes several, significant problems that are very distressing.

E. My gambling is very difficult but not impossible to control, even though it causes several problems.

Now please turn to page 16.
Set F

A. I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.

B. Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.

C. I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems although I do think about cutting back from time to time.

D. Although my gambling is relatively difficult to control, it causes few but only minor problems.

E. My gambling is very difficult but not impossible to control, even though it causes several problems.

F. My gambling is impossible to control and it causes severe, significant problems that are very distressing.

Now please turn to the next page.
Task Three

Here your task is to rank the six statements in the order of your agreement with them. Number the statements from the one you agree with most strongly (1) up to the one you disagree with the most strongly (6).

I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.

Although I feel a need to control my gambling, it is easily controlled without conscious effort and it does not cause any problems.

I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause problems yet I do think about cutting back from time to time.

Although my gambling is relatively difficult to control, it causes few but only minor problems.

My gambling is very difficult but not impossible to control, even though it causes several problems.

My gambling is impossible to control and it causes several, significant problems that are very distressing.

Now please turn to the next page.
Task Four

The statements in the following group express levels of individual control over time spent gambling. Just as you did for the last group of statements, please read through all of the statements below and then tick the statement nearest to your own level. That is, find the statement that you agree with the most and then tick that statement. Please tick one and only one statement.

A. I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

B. Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

C. I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

D. It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

E. It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

F. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

Now the statements are presented to you in pairs. Your task is to judge for each pair of statements the one that you agree with the most.

However, you do not need to do this for all of the following pairs of statements. Go straight to the set with the same label as the statement you ticked. That is, if you ticked statement A, go to the set labelled A; if you ticked B, go to the set labelled B; and so on. Within that set make a judgement for each pair, ticking the statement in each pair that you agree with the most. Please respond to all pairs in your set. In your set, tick one and only one statement within each pair.

Immediately below each set of paired statements there is a prompt which will ask you to turn to a particular page. Please turn to that page and follow the instructions.
Set A

D. It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

E. It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

B. Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

C. I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

F. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

E. It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

B. Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

A. I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

C. I feel a need to limit the time I spend gambling and while it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

D. It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

Now please turn to page 24.
Set B

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B.</td>
<td>Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.</td>
</tr>
<tr>
<td>C.</td>
<td>I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.</td>
</tr>
<tr>
<td>E.</td>
<td>It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.</td>
</tr>
<tr>
<td>D.</td>
<td>It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.</td>
</tr>
<tr>
<td>C.</td>
<td>I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.</td>
</tr>
<tr>
<td>F.</td>
<td>It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.</td>
</tr>
</tbody>
</table>

Now please turn to page 24.
Set C

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>E.</td>
<td>It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.</td>
</tr>
<tr>
<td>B.</td>
<td>Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.</td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.</td>
</tr>
<tr>
<td>F.</td>
<td>It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes significant problems that are very distressing.</td>
</tr>
<tr>
<td>B.</td>
<td>Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.</td>
</tr>
<tr>
<td>D.</td>
<td>It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.</td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.</td>
</tr>
<tr>
<td>E.</td>
<td>It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.</td>
</tr>
<tr>
<td>F.</td>
<td>It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td>B.</td>
<td>Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.</td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.</td>
</tr>
<tr>
<td>D.</td>
<td>It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.</td>
</tr>
</tbody>
</table>

Now please turn to page 24.
Set D

C.  I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

E.  It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

F.  It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

B.  Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

A.  I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

E.  It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

C.  I feel a need to limit the time I spend gambling and whilst it is easily limited, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

F.  It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

E.  It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

B.  Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

A.  I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

F.  It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

Now please turn to page 24.
F. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

E. It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

F. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

D. It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

C. I feel a need to limit the time I spend gambling and whilst it is easily limited, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

F. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

F. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

B. Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

A. I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

F. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

Now please turn to page 24.
Set F

D. It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

E. It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

B. Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

C. I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

F. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

E. It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

C. I feel a need to limit the time I spend gambling and while it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

D. It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

B. Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

A. I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

Now please turn to the next page.
Task Five

Here your task is to rank the six statements in the order of your agreement with them. Number the statements from the one you agree with most strongly (1) up to the one you disagree with the most strongly (6).

I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

Now please turn to the next page.
Task Six

The statements in the following group express levels of individual control over impulses to gamble. Just as you did for the previous questionnaires, it is very important that you read through each of the statements carefully and then tick the statement nearest to your own level. That is, find the statement that you agree with most and then tick that statement. Please tick one and only one statement.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

B. I sometimes experience strong impulses to gamble, but I can easily resist them without any conscious effort and my gambling does not cause any problems.

C. I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause any problems.

D. I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

E. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

Now the statements are presented to you in pairs. Your task is to judge for each pair of statements the one that you agree with the most. However, you do not need to do this for all of the following pairs of statements. Go straight to the set with the same label as the statement you ticked. That is, if you ticked statement A, go to the set labelled A; if you ticked B, go to the set labelled B; and so on. Within that set make a judgement for each pair, ticking the statement in each pair that you agree with the most. In your set, tick one and only one statement within each pair. Please respond to all pairs in your set.

Immediately below each set of paired statements there is a prompt which will ask you to turn to a particular page. Please turn to that page and follow the instructions.
### Set A

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>F.</strong></td>
<td>My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td><strong>E.</strong></td>
<td>The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.</td>
</tr>
<tr>
<td><strong>B.</strong></td>
<td>I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause problems.</td>
</tr>
<tr>
<td><strong>C.</strong></td>
<td>I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort, but my gambling does not cause problems.</td>
</tr>
<tr>
<td><strong>A.</strong></td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.</td>
</tr>
<tr>
<td><strong>B.</strong></td>
<td>I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause any problems.</td>
</tr>
<tr>
<td><strong>E.</strong></td>
<td>The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.</td>
</tr>
<tr>
<td><strong>D.</strong></td>
<td>I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.</td>
</tr>
<tr>
<td><strong>C.</strong></td>
<td>I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort, but my gambling does not cause any problems.</td>
</tr>
<tr>
<td><strong>D.</strong></td>
<td>I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.</td>
</tr>
</tbody>
</table>

Now please turn to page 32.
Set B

A. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

D. I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

C. I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause any problems.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

E. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

B. I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause problems.

C. I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause problems.

Now please turn to page 32.
<table>
<thead>
<tr>
<th>Set C</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.</td>
</tr>
<tr>
<td>B. I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause any problems.</td>
</tr>
<tr>
<td>A. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.</td>
</tr>
<tr>
<td>E. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.</td>
</tr>
<tr>
<td>F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td>A. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.</td>
</tr>
<tr>
<td>F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td>B. I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause any problems.</td>
</tr>
<tr>
<td>B. I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause any problems.</td>
</tr>
<tr>
<td>E. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.</td>
</tr>
<tr>
<td>A. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.</td>
</tr>
<tr>
<td>D. I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.</td>
</tr>
</tbody>
</table>

Now please turn to page 32.
Set D

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>F.</td>
<td>My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td>C.</td>
<td>I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause any problems.</td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.</td>
</tr>
<tr>
<td>E.</td>
<td>The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.</td>
</tr>
<tr>
<td>B.</td>
<td>I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause any problems.</td>
</tr>
<tr>
<td>E.</td>
<td>The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.</td>
</tr>
</tbody>
</table>

Now please turn to page 32.
Set E

D. I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

C. I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause any problems.

F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

B. I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause any problems.

F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

E. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

Now please turn to page 32.
Set F

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C.</td>
<td>I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause any problems.</td>
</tr>
<tr>
<td>D.</td>
<td>I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>F.</td>
<td>My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td>E.</td>
<td>The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.</td>
</tr>
<tr>
<td>B.</td>
<td>I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause any problems.</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>E.</td>
<td>The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.</td>
</tr>
<tr>
<td>D.</td>
<td>I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B.</td>
<td>I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause problems.</td>
</tr>
<tr>
<td>C.</td>
<td>I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort, but my gambling does not cause problems.</td>
</tr>
</tbody>
</table>

Now please turn to the next page.
Task Seven

Here your task is to rank the six statements in the order of your agreement with them. Number the statements from the one you agree with the most strongly (1) up to the one you disagree with the most strongly (6).

I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

I sometimes experience strong impulses to gamble, but I can easily resist them without any conscious effort and my gambling does not cause any problems.

I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause any problems.

I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

You are now finished.
Appendix 17: The SGC (Baron et al, 1995; O’Connor, 1995) questionnaire booklet. This version commenced with the Baron et al version; the other with the O’Connor.

UWS, Macarthur: Department of Psychology

The following 2 questionnaires are different to the ones you have just completed. These questionnaires are very similar and both ask you more about your gambling behaviour. Specifically, they ask about your gambling behaviour during the past 6 months. It is very important that you complete these questionnaires carefully and honestly. Please do not answer the statements carelessly.

The first questionnaire starts on the next page. One this page there are 6 statements. Under each statement there is a 5 point scale with the words “never”, “rarely”, “sometimes”, “often” and “always”. For each of the six statements, please circle the word on the scale that best describes how often that statement applied to you during the past 6 months. If a statement does not apply to you, please tick the box that is next to the scale on the right hand side.

On the following two pages there are 12 different statements with the same 5 point scale underneath them. For these 12 statements, please circle the word on the scale that best describes how often you have actually experienced that statement during the past six months. If a statement does not apply to you, please tick the box at the end of the scale on the right hand side.

There are no right or wrong answers. Please answer each statement as carefully as you can.
1. I tried to gamble less often.

Never  Rarely  Sometimes  Often  Always  Does not apply

2. I tried to spend less on my gambling.

Never  Rarely  Sometimes  Often  Always  Does not apply

3. I tried to resist the opportunity to start gambling.

Never  Rarely  Sometimes  Often  Always  Does not apply

4. I tried to stop gambling for a period of time.

Never  Rarely  Sometimes  Often  Always  Does not apply

5. I tried to limit the amount I gamble.

Never  Rarely  Sometimes  Often  Always  Does not apply

6. I tried to stop gambling once I had reached self-imposed limits.

Never  Rarely  Sometimes  Often  Always  Does not apply
1. I have been able to stop gambling before I spent all of my spare cash.
   Never  Rarely  Sometimes  Often  Always  Does not apply

2. I’ve been able to stop easily after a few games or bets.
   Never  Rarely  Sometimes  Often  Always  Does not apply

3. I’ve been able to stop gambling before I got into debt.
   Never  Rarely  Sometimes  Often  Always  Does not apply

4. I’ve been able to stop gambling before the last race, TAB, club, hotel or casino closed.
   Never  Rarely  Sometimes  Often  Always  Does not apply

5. When I’ve wanted to I’ve been able to gamble less often.
   Never  Rarely  Sometimes  Often  Always  Does not apply

6. I’ve been able to resist the urge to start gambling.
   Never  Rarely  Sometimes  Often  Always  Does not apply

7. I’ve been able to gamble less often when I’ve wanted to.
   Never  Rarely  Sometimes  Often  Always  Does not apply
8. When I’ve wanted to I could stop gambling for a week or more.

Never  Rarely  Sometimes  Often  Always  Does not apply

9. When I have been near a club/hotel, TAB or casino I have found it difficult to resist gambling.

Never  Rarely  Sometimes  Often  Always  Does not apply

10. I have found it difficult to limit how much I gamble.

Never  Rarely  Sometimes  Often  Always  Does not apply

11. Even for a single day I’ve found it difficult to resist gambling.

Never  Rarely  Sometimes  Often  Always  Does not apply

12. One I have started gambling I have an irresistible urge to continue.

Never  Rarely  Sometimes  Often  Always  Does not apply

Now please turn to the next page.
The following questionnaire is very similar to the one you have just completed. But there are some important differences.

This questionnaire contains 12 statements. Under each statement there is a 5 point scale. In this questionnaire, however, the words on the scale are different. They are “very rarely”, “rarely”, “sometimes”, “often” and “very often”. Please circle the word that best describes how often you have actually attempted to limit your gambling during the past 6 months. If you have tried to resist gambling but never have actually succeeded, please circle the words “very rarely”.

If a statement does not apply because you have made no attempt to limit your gambling in the last six months, please tick the box that is at the end of each scale on the right hand side. For example, a statement might ask you how often during the last 6 months you were able to resist the urge to start gambling. If you made no attempt to resist the urge to gamble in the last six months then you would tick the box. You would only circle the words “very rarely” if you tried to resist gambling but were never able to succeed. Please tick the box as often as you think necessary.

There are no right or wrong answers. Please answer each statement as carefully as you can.
1. I have found it difficult to limit how much I gamble.

<table>
<thead>
<tr>
<th>Very rarely</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
<th>Does not apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. When I have been near a club/hotel, TAB or casino I have found it difficult to resist gambling.

<table>
<thead>
<tr>
<th>Very rarely</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
<th>Does not apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. When I have wanted to I have been able to gamble less often.

<table>
<thead>
<tr>
<th>Very rarely</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
<th>Does not apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. I have been able to stop easily after a few games or bets.

<table>
<thead>
<tr>
<th>Very rarely</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
<th>Does not apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. I have been able to stop gambling before I spent all my spare cash.

<table>
<thead>
<tr>
<th>Very rarely</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
<th>Does not apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. I have been able to resist the urge to start gambling.

<table>
<thead>
<tr>
<th>Very rarely</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
<th>Does not apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. Once I have started gambling I have an irresistible urge to continue.

<table>
<thead>
<tr>
<th>Very rarely</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
<th>Does not apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. When I have wanted to I could stop gambling for a week or more.

<table>
<thead>
<tr>
<th>Very rarely</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
<th>Does not apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. I have been able to stop gambling before the last race, TAB, club, or casino closed.

<table>
<thead>
<tr>
<th>Very rarely</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
<th>Does not apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
10. Even for a single day I have found it difficult to resist gambling.

<table>
<thead>
<tr>
<th>Very rarely</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
<th>Does not apply</th>
</tr>
</thead>
</table>

11. I have been able to gamble less often when I’ve wanted to.

<table>
<thead>
<tr>
<th>Very rarely</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
<th>Does not apply</th>
</tr>
</thead>
</table>

12. I have been able to stop gambling before I got into debt.

<table>
<thead>
<tr>
<th>Very rarely</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
<th>Does not apply</th>
</tr>
</thead>
</table>

You are now finished these questionnaires.
Appendix 18: Retest phase Subjective Control Scale questionnaire booklet administered to participants.

Participant No.: 

UWS, Macarthur

Task One Instructions

The following questionnaires are going to ask you about your gambling behaviour again. This is done to check how reliable the questionnaire is. It is very important that you do not make ad-hoc or careless responses in this entire exercise. Please make all of your responses very carefully.

What I want you to do are the seven tasks again. The instructions are exactly the same as they were last time. This is not designed to trick you in any way. Just complete the questionnaires the same as you did previously.

There are no right or wrong answers. Your responses should be your own so ignore the responses made by anyone else. Please read each statement very carefully. Complete the questionnaires at your own pace and as accurately as you can.

Please do not write your name on any of the questionnaires. You may begin and I will be on hand to answer any questions you may have.
Set One

1. I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause any problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. I sometimes experience strong impulses to gamble, but I can easily resist them without any conscious effort and my gambling does not cause any problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Set Two**

1. I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

6. I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.
1. My gambling is impossible to control and it causes several, significant problems that are very distressing.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause problems yet I do think about cutting back from time to time.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. My gambling is very difficult but not impossible to control, even though it causes several problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Although I feel a need to control my gambling, it is easily controlled without conscious effort and it does not cause any problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Although my gambling is relatively difficult to control, it causes few but only minor problems.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree to Some Extent</td>
<td>Fairly Neutral</td>
<td>Agree to Some Extent</td>
<td>Strongly Agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Task Two

The statements in the following group express levels of individual control over impulses to gamble. It is very important that you read through each of the statements carefully and then tick the statement nearest to your own level. That is, find the statement that you agree with most and then tick that statement. Please tick one and only one statement.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

B. I sometimes experience strong impulses to gamble, but I can easily resist them without any conscious effort and my gambling does not cause any problems.

C. I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause any problems.

D. I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

E. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

Now the statements are presented to you in pairs. Your task is to judge for each pair of statements the one that you agree with the most. However, you do not need to do this for all of the following pairs of statements. Go straight to the set with the same label as the statement you ticked. That is, if you ticked statement A, go to the set labelled A; if you ticked B, go to the set labelled B; and so on. Within that set make a judgement for each pair, ticking the statement in each pair that you agree with the most. In your set, tick one and only one statement within each pair. Please respond to all pairs in your set.

Immediately below each set of paired statements there is a prompt which will ask you to turn to a particular page. Please turn to that page and follow the instructions.
Set A

F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several significant problems that are very distressing.

E. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

B. I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause problems.

C. I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort, but my gambling does not cause problems.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

B. I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause any problems.

E. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

D. I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

C. I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort, but my gambling does not cause any problems.

D. I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

Now please turn to page 15.
Set B

<table>
<thead>
<tr>
<th>A.</th>
<th>I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.</td>
<td>I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A.</th>
<th>I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.</td>
<td>I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause any problems.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A.</th>
<th>I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.</td>
<td>The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>F.</th>
<th>My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B.</th>
<th>I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause problems.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.</td>
<td>I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause problems.</td>
</tr>
</tbody>
</table>

Now please turn to page 15.
Set C

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.</td>
</tr>
<tr>
<td>B</td>
<td>I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause any problems.</td>
</tr>
<tr>
<td>A</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.</td>
</tr>
<tr>
<td>E</td>
<td>The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.</td>
</tr>
<tr>
<td>F</td>
<td>My frequent, strong impulses to gamble are impossible to resist and my gambling causes several significant problems that are very distressing.</td>
</tr>
<tr>
<td>A</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.</td>
</tr>
<tr>
<td>B</td>
<td>I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause any problems.</td>
</tr>
</tbody>
</table>

Now please turn to page 15.
Set D

F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

C. I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort, but my gambling does not cause any problems.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

E. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

B. I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause any problems.

E. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

B. I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause any problems.

F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

C. I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort, but my gambling does not cause problems.

E. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

Now please turn to page 15.
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D.</strong></td>
<td>I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.</td>
</tr>
<tr>
<td><strong>E.</strong></td>
<td>The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.</td>
</tr>
<tr>
<td><strong>F.</strong></td>
<td>My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td><strong>C.</strong></td>
<td>I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort, but my gambling does not cause any problems.</td>
</tr>
<tr>
<td><strong>B.</strong></td>
<td>I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause any problems.</td>
</tr>
<tr>
<td><strong>A.</strong></td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.</td>
</tr>
</tbody>
</table>

Now please turn to page 15.
Set F

C. I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort, but my gambling does not cause any problems.

D. I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

F. My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

E. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

A. I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

B. I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause any problems.

E. The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

D. I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

B. I sometimes experience strong impulses to gamble, but I can easily resist them without conscious effort and my gambling does not cause problems.

C. I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort, but my gambling does not cause problems.

Now please turn to the next page.
Task Three

Here your task is to rank the six statements in the order of your agreement with them. Number the statements from the one you agree with the most strongly (1) up to the one you disagree with the most strongly (6).

I am free to gamble at my leisure as it does not cause any problems and I never experience strong impulses to gamble.

I sometimes experience strong impulses to gamble, but I can easily resist them without any conscious effort and my gambling does not cause any problems.

I sometimes feel strong impulses to gamble and while easily resisted, it does take some conscious effort; but my gambling does not cause any problems.

I often have strong impulses to gamble that are difficult to resist, but not very difficult, and my gambling causes few but only minor problems.

The strong impulses to gamble I often have are very difficult, but not impossible, to resist even though my gambling causes several problems.

My frequent, strong impulses to gamble are impossible to resist and my gambling causes several, significant problems that are very distressing.

Now please turn to the next page.
Task Four

The statements in the following group express levels of individual control over time spent gambling. Just as you did for the last group of statements, please read through all of the statements below and then tick the statement nearest to your own level. That is, find the statement that you agree with the most and then tick that statement. Please tick one and only one statement.

A. I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

B. Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

C. I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

D. It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

E. It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

F. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

Now the statements are presented to you in pairs. Your task is to judge for each pair of statements the one that you agree with the most.

However, you do not need to do this for all of the following pairs of statements. Go straight to the set with the same label as the statement you ticked. That is, if you ticked statement A, go to the set labelled A; if you ticked B, go to the set labelled B; and so on. Within that set make a judgement for each pair, ticking the statement in each pair that you agree with the most. Please respond to all pairs in your set. In your set, tick one and only one statement within each pair.

Immediately below each set of paired statements there is a prompt which will ask you to turn to a particular page. Please turn to that page and follow the instructions.
Set A

D. It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

E. It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

B. Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

C. I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

F. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

E. It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

B. Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

A. I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

C. I feel a need to limit the time I spend gambling and while it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

D. It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

Now please turn to page 23.
<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B.</td>
<td>Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.</td>
<td>I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E.</td>
<td>It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D.</td>
<td>It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.</td>
<td>I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F.</td>
<td>It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Now please turn to page 23.
Set C

<table>
<thead>
<tr>
<th>A.</th>
<th>I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.</td>
<td>Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.</td>
</tr>
<tr>
<td>C.</td>
<td>It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes severe problems.</td>
</tr>
<tr>
<td>D.</td>
<td>It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.</td>
</tr>
<tr>
<td>E.</td>
<td>It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several significant problems that are very distressing.</td>
</tr>
</tbody>
</table>

Now please turn to page 23.
Set D

C. I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

E. It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

F. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

B. Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

A. I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

E. It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

C. I feel a need to limit the time I spend gambling and whilst it is easily limited, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

F. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

E. It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

B. Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

A. I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

F. It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

Now please turn to page 23.
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>E.</td>
<td>It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.</td>
</tr>
<tr>
<td>F.</td>
<td>It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td>D.</td>
<td>It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.</td>
</tr>
<tr>
<td>C.</td>
<td>I feel a need to limit the time I spend gambling and whilst it is easily limited, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.</td>
</tr>
<tr>
<td>F.</td>
<td>It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td>B.</td>
<td>Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.</td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.</td>
</tr>
<tr>
<td>F.</td>
<td>It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.</td>
</tr>
</tbody>
</table>

Now please turn to page 23.
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Set F</strong></td>
<td></td>
</tr>
<tr>
<td><strong>D.</strong> It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.</td>
<td></td>
</tr>
<tr>
<td><strong>E.</strong> It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.</td>
<td></td>
</tr>
<tr>
<td><strong>B.</strong> Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.</td>
<td></td>
</tr>
<tr>
<td><strong>C.</strong> I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.</td>
<td></td>
</tr>
<tr>
<td><strong>F.</strong> It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.</td>
<td></td>
</tr>
<tr>
<td><strong>E.</strong> It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.</td>
<td></td>
</tr>
<tr>
<td><strong>C.</strong> I feel a need to limit the time I spend gambling and while it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.</td>
<td></td>
</tr>
<tr>
<td><strong>D.</strong> It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.</td>
<td></td>
</tr>
<tr>
<td><strong>B.</strong> Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.</td>
<td></td>
</tr>
<tr>
<td><strong>A.</strong> I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.</td>
<td></td>
</tr>
</tbody>
</table>

Now please turn to the next page.
Task Five

Here your task is to rank the six statements in the order of your agreement with them. Number the statements from the one you agree with most strongly (1) up to the one you disagree with the most strongly (6).

I am free to gamble at my leisure as it does not cause any problems and I do not experience any need to limit the time I spend gambling.

Although I feel a need to limit the time I spend gambling, it is easily limited without conscious effort and it does not cause any problems.

I feel a need to limit the time I spend gambling and whilst it is relatively easy to limit, limiting it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

It is relatively difficult for me to limit the time I spend gambling and it sometimes interferes with other activities and causes few but only minor problems.

It is very difficult, but not impossible, for me to limit the time I spend gambling even though my gambling often interferes with other activities and causes several problems.

It is impossible for me to limit the time I spend gambling and it often interferes with other activities and causes several, significant problems that are very distressing.

Now please turn to the next page.
Task Six

The statements in the following group express levels of individual control over gambling behaviour. Just as you did for the last group of statements, it is very important that you read through each of the statements carefully and then **tick the statement nearest to your own level.** That is, find the statement that **you agree with most and then tick that statement.** Tick one statement only. **Your response should be your own, so please ignore the responses being made by anyone else.**

A. I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.

B. Although I feel a need to control my gambling, it is easily controlled without conscious effort and it does not cause any problems.

C. I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause problems yet I do think about cutting back from time to time.

D. Although my gambling is relatively difficult to control, it causes few but only minor problems.

E. My gambling is very difficult but not impossible to control, even though it causes several problems.

F. My gambling is impossible to control and it causes several, significant problems that are very distressing.

Now the statements are presented to you in pairs. Your task is to judge for each pair of statements the one that you agree with the most. However, you do not need to do this for all of the following pairs of statements. Go straight to the set with the same label as the statement you ticked. That is, if you ticked Statement A, go to the set labelled A; if you ticked B, go to the set labelled B; and so on. Within each set make a judgment for each pair, ticking the statement in each pair that you agree with the most. Please tick **one and only one** statement in each pair. Please respond to all pairs in your set.

Immediately below each set of paired statements there is a prompt which will ask you to turn to a particular page. Please turn to that page and follow the instructions.
D. I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems although I do think about cutting back from time to time.

D. Although my gambling is relatively difficult to control, it causes few but only minor problems.

G. I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.

H. Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.

F. My gambling is impossible to control and it causes several, significant problems that are very distressing.

E. My gambling is very difficult but not impossible to control, even though it causes several problems.

C. I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.

B. Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.

E. My gambling is very difficult but not impossible to control, even though it causes several problems.

D. Although my gambling is relatively difficult to control, it causes few but only minor problems.

Now please turn to page 31.
### Set B

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.</td>
</tr>
<tr>
<td>F.</td>
<td>My gambling is impossible to control and it causes several, significant problems that are very distressing.</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.</td>
</tr>
<tr>
<td>C.</td>
<td>I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D.</td>
<td>Although my gambling is relatively difficult to control, it causes few but only minor problems.</td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>E.</td>
<td>My gambling is very difficult but not impossible to control, even though it causes several problems.</td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C.</td>
<td>I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.</td>
</tr>
<tr>
<td>B.</td>
<td>Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.</td>
</tr>
</tbody>
</table>

Now please turn to page 31.
### Set C

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D.</strong> Although my gambling is relatively difficult to control, it causes few but only minor problems.</td>
<td></td>
</tr>
<tr>
<td><strong>A.</strong> I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.</td>
<td></td>
</tr>
<tr>
<td><strong>B.</strong> Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.</td>
<td></td>
</tr>
<tr>
<td><strong>F.</strong> My gambling is impossible to control and it causes several, significant problems that are very distressing.</td>
<td></td>
</tr>
<tr>
<td><strong>E.</strong> My gambling is very difficult but not impossible to control, even though it causes several problems.</td>
<td></td>
</tr>
<tr>
<td><strong>A.</strong> I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.</td>
<td></td>
</tr>
</tbody>
</table>

Now please turn to page 31.
Set D

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>F.</td>
<td>My gambling is impossible to control and it causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>B.</td>
<td>Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>E.</td>
<td>My gambling is very difficult but not impossible to control, even though it causes several problems.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>C.</td>
<td>I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>F.</td>
<td>My gambling is impossible to control and it causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>E.</td>
<td>My gambling is very difficult but not impossible to control, even though it causes several problems.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>B.</td>
<td>Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>F.</td>
<td>My gambling is impossible to control and it causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>E.</td>
<td>My gambling is very difficult but not impossible to control, even though it causes several problems.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>C.</td>
<td>I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems yet I do think about cutting back from time to time.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Now please turn to page 31.
Set E

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.</td>
</tr>
<tr>
<td>F</td>
<td>My gambling is impossible to control and it causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td>B</td>
<td>Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.</td>
</tr>
<tr>
<td>F</td>
<td>My gambling is impossible to control and it causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td>C</td>
<td>I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort, but it does not cause any problems yet I do think about cutting back from time to time.</td>
</tr>
<tr>
<td>F</td>
<td>My gambling is impossible to control and it causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td>D</td>
<td>Although my gambling is relatively difficult to control, it causes few but only minor problems.</td>
</tr>
<tr>
<td>F</td>
<td>My gambling is impossible to control and it causes several, significant problems that are very distressing.</td>
</tr>
<tr>
<td>E</td>
<td>My gambling is very difficult but not impossible to control, even though it causes several problems.</td>
</tr>
</tbody>
</table>

Now please turn to page 31.
Set F

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B. I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.</td>
<td></td>
</tr>
<tr>
<td>1. Although I feel a need to control my gambling, it is easily controlled without any conscious effort and it does not cause any problems.</td>
<td></td>
</tr>
<tr>
<td>C. I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause any problems although I do think about cutting back from time to time.</td>
<td></td>
</tr>
<tr>
<td>D. Although my gambling is relatively difficult to control, it causes few but only minor problems.</td>
<td></td>
</tr>
<tr>
<td>F. My gambling is impossible to control and it causes several, significant problems that are very distressing.</td>
<td></td>
</tr>
<tr>
<td>E. My gambling is very difficult but not impossible to control, even though it causes several problems.</td>
<td></td>
</tr>
</tbody>
</table>

---

Now please turn to the next page.
Task Seven

Here your task is to rank the six statements in the order of your agreement with them. Number the statements from the one you agree with most strongly (1) up to the one you disagree with the most strongly (6).

I am free to gamble at my leisure as it does not cause any problems and I never experience any need to control my gambling at all.

Although I feel a need to control my gambling, it is easily controlled without conscious effort and it does not cause any problems.

I feel a need to control my gambling and whilst it is relatively easy to control, controlling it does require conscious effort; but it does not cause problems yet I do think about cutting back from time to time.

Although my gambling is relatively difficult to control, it causes few but only minor problems.

My gambling is very difficult but not impossible to control, even though it causes several problems.

My gambling is impossible to control and it causes several, significant problems that are very distressing.

You are now finished.
Appendix 19. Correlation matrices of the rating scale data of the Subjective Control scales.

Table 1. Correlation matrix of the rating scale data for the general version – test condition (n = 210)

<table>
<thead>
<tr>
<th></th>
<th>Statement A</th>
<th>Statement B</th>
<th>Statement C</th>
<th>Statement D</th>
<th>Statement E</th>
<th>Statement F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement A</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement B</td>
<td>.320**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement C</td>
<td>-.473**</td>
<td>-.002</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement D</td>
<td>-.252**</td>
<td>.107</td>
<td>.493**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement E</td>
<td>-.494**</td>
<td>-.067</td>
<td>.574**</td>
<td>.579**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Statement F</td>
<td>-.645**</td>
<td>-.283**</td>
<td>.536**</td>
<td>.342**</td>
<td>.584**</td>
<td>1</td>
</tr>
</tbody>
</table>

**p < .01, two tailed test

Table 2. Correlation matrix of the rating scale data for the general version – retest condition (n = 210)

<table>
<thead>
<tr>
<th></th>
<th>Statement A</th>
<th>Statement B</th>
<th>Statement C</th>
<th>Statement D</th>
<th>Statement E</th>
<th>Statement F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement A</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement B</td>
<td>.218**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement C</td>
<td>-.361**</td>
<td>.332**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement D</td>
<td>-.439**</td>
<td>.133*</td>
<td>.527**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement E</td>
<td>-.670**</td>
<td>-.116*</td>
<td>.453**</td>
<td>.581**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Statement F</td>
<td>-.736**</td>
<td>-.263**</td>
<td>.249**</td>
<td>.271**</td>
<td>.647**</td>
<td>1</td>
</tr>
</tbody>
</table>

*p < .05; **p < .01, two tailed test

Table 3. Correlation matrix of the rating scale data for the time involvement version – test condition (n = 209)

<table>
<thead>
<tr>
<th></th>
<th>Statement A</th>
<th>Statement B</th>
<th>Statement C</th>
<th>Statement D</th>
<th>Statement E</th>
<th>Statement F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement A</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement B</td>
<td>-.307**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement C</td>
<td>-.210**</td>
<td>.277**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement D</td>
<td>-.461**</td>
<td>-.040</td>
<td>.467**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement E</td>
<td>-.553**</td>
<td>-.108</td>
<td>.445**</td>
<td>.650**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Statement F</td>
<td>-.601**</td>
<td>-.254**</td>
<td>.247**</td>
<td>.637**</td>
<td>.602**</td>
<td>1</td>
</tr>
</tbody>
</table>

**p < .01, two tailed test

Table 4. Correlation matrix of the rating scale data for the time involvement version – retest condition (n = 209)

<table>
<thead>
<tr>
<th></th>
<th>Statement A</th>
<th>Statement B</th>
<th>Statement C</th>
<th>Statement D</th>
<th>Statement E</th>
<th>Statement F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement A</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement B</td>
<td>.182**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement C</td>
<td>-.249**</td>
<td>.376**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement D</td>
<td>-.520**</td>
<td>-.057</td>
<td>.450**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement E</td>
<td>-.467**</td>
<td>.006</td>
<td>.438**</td>
<td>.674**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Statement F</td>
<td>-.663**</td>
<td>-.257**</td>
<td>.235**</td>
<td>.725**</td>
<td>.623**</td>
<td>1</td>
</tr>
</tbody>
</table>

**p < .01, two tailed test
Table 5. Correlation matrix of the rating scale data for the impulses to gamble version – test condition (n = 209)

<table>
<thead>
<tr>
<th></th>
<th>Statement A</th>
<th>Statement B</th>
<th>Statement C</th>
<th>Statement D</th>
<th>Statement E</th>
<th>Statement F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement A</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement B</td>
<td>0.268**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement C</td>
<td>0.019</td>
<td>0.550**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement D</td>
<td>-0.344**</td>
<td>0.209**</td>
<td>0.430**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement E</td>
<td>-0.528**</td>
<td>-0.013</td>
<td>0.302**</td>
<td>0.565**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Statement F</td>
<td>-0.662**</td>
<td>-0.225**</td>
<td>0.027</td>
<td>0.264**</td>
<td>0.559**</td>
<td>1</td>
</tr>
</tbody>
</table>

** p < .01, two tailed test

Table 6. Correlation matrix of the rating scale data for the time involvement version – retest condition (n = 209)

<table>
<thead>
<tr>
<th></th>
<th>Statement A</th>
<th>Statement B</th>
<th>Statement C</th>
<th>Statement D</th>
<th>Statement E</th>
<th>Statement F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement A</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement B</td>
<td>0.191**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement C</td>
<td>-0.123*</td>
<td>0.495**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement D</td>
<td>-0.356**</td>
<td>0.219**</td>
<td>0.456**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statement E</td>
<td>-0.567**</td>
<td>-0.023</td>
<td>0.293**</td>
<td>0.565**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Statement F</td>
<td>-0.673**</td>
<td>-0.221**</td>
<td>0.139*</td>
<td>0.357**</td>
<td>0.553**</td>
<td>1</td>
</tr>
</tbody>
</table>

* p < .05; ** p < .01, two tailed test
Appendix 20. Exploratory and confirmatory factor analyses of the two versions of the Scale of Gambling Choices (Baron, Dickerson & Blaszczyński, 1995, O’Connor, 2000).

The favoured statistical tool employed by psychometricians in the development of psychometric apparatus is factor analysis (Thurstone, 1947; Kline, 1998); a statistical technique accredited to the early quantitative psychologist Charles Spearman (1904) and his work on intelligence testing. The basic orthogonal (additive, non-correlated) factor analysis model is a simple extension of the basic multiple regression model:

\[ z_j = F_{k1}Z_{n1} + F_{k2}Z_{n2} + \ldots + F_{kn}Z_{nn} + \varepsilon_{FZ} \quad 1. \]

where \( z_j \) is \( i \)'s total score on test \( j \) in standardised form, \( \langle Z_{n1}, Z_{n2}, \ldots, Z_{nn} \rangle \) is a vector of the unobserved, standardised ‘amounts’ that \( i \) ‘possesses’ of \( n \) unobserved, latent factors, \( \langle F_{k1}, F_{k2}, \ldots, F_{kn} \rangle \) is a vector of observed weights or ‘loadings’ derived from the data upon the \( n \) and \( \varepsilon_{FZ} \) is the total error term (Harris, 2001; Johnson & Wichern, 1998). The vector of \( Z \) scores can be interpreted as \( i \)'s ‘true’ scores and \( F \) loadings indicate the degree to which the test ‘measures’ the unobserved factors. These loadings range between 0 and 1 and ideally should approach or be close to 1 if the test is a good measure of the unobserved factors. If the factor analysis results in the above orthogonal model, then each of the \( F \)'s can be squared and then summed to give the communality of an item within the test, which indicates how much of the observed score variance the factor analysis model accounts for (Kline, 1998).

An infinite number of sets of factor loadings and \( Z \) scores could be produced such that Equation 1 is satisfied. Thus it is impossible for any psychometrician using factor analysis to conclude that any orthogonal factorial solution obtained out of the infinite number of such solutions is in fact the “true” solution. Additionally, Equation 1 does not present arguments as to exactly how many factors will present in any given solution. All it argues is that there will be \( n \) such factors for any finite, countable \( n \). Thus it is possible via Equation 1 that any obtained factorial solution may possess factors (possibly a multitude of factors) quite unrelated to the attribute or attributes of interest. Additionally, it argues for a linear, additive composition function between the terms of the right hand side of Eqn. 1. The factor analysis model gives no good reason as to why human behaviour should operate to satisfy this particular composition function. It could well be that that the true composition function is multiplicative, distributive, quadratic or even cubic. The factor analysis model does not allow the existence of such functions for
obvious statistical reasons. Data, however, should not be forced to satisfy a particular model. Rather, the model should withstand a test of the data.

Despite its firm basis as an elegant and sophisticated statistical theory of observed and inter-correlated data known already to be quantitative, factor analysis is an inadequate quantitative theory of psychology. Equation 1 in no way can predict the number of factors that will occur in any factorial simple structure solution as the number of factors present in any solution is always determined post hoc. This is problematic as the psychometrician has no facility to hypothesise exactly which factors (which are often directly interpreted as dimensions of the mind) will both present and combine in the manner prescribed by Eqn. 1 to predict an individual’s standard score upon a particular psychometric test. This renders factor analysis of little scientific value. It is at best a tool from which hypotheses concerning obtained data can be made, not tested. It is partly for this reason that structural equation modelling and its allied procedure of confirmatory factor analysis has increased enormously in use over the past 20 years (Schumacker & Lomax, 1996).

The empirical subject of this appendix is the Scale of Gambling Choices (SGC) (Baron, Dickerson & Blaszczynski, 1995; O’Connor, 2000). The initial development of this scale has already been outlined in Chapter 4 and hence no further commentary on it will be entered into except for its psychometric properties.

7.2 Study 1: An attempt to replicate the factor structure of the Baron et al (1995) SGC.

7.2.1 Design

Factor analysis – based anonymous questionnaire design. The questionnaire consisted of two parts. The first part consisted of 6 items that purported to assess actual attempts to control various gambling behaviours. Underneath each statement there was a 5 – point Likert type rating scale. The scale consisted of the positive integer numerals of 1, 2, 3, 4 and 5 which were above, respectively, the semantic categories of ‘never’, ‘rarely’, ‘sometimes’, ‘often’ and ‘always’. Underneath each rating scale was a box labelled ‘this does not apply to me’ which was scored as 0.

The second part of the questionnaire consisted of 12 items that purported to assess experiences of control over gambling. Underneath each item was a rating scale identical to those used in the first section.

7.2.2 Participants
The data given by participants who completed the SGC as a part of their participation in three other studies were compiled and used in this study. The participants were:

i. A convenience sample of 226 poker machine players from a study conducted by Shepherd (thesis). Thirty – two percent were aged 18 – 25 years of age; 28% aged 26 – 34; 17% aged 35 – 44; 10% aged 45 – 54; 5% aged 55 – 64; and 8% were 65 years or older. All participants were recruited from 6 licensed hotels in the Sydney metropolitan area and the only criterion for participation was that they had gambled on a poker machine ‘at least several times’ previously. All participants received A$5 for their participation.

ii. A convenience sample of 40 males over the age of 18 years who partook in Kyngdon & Dickerson’s (1999) study. The mean age of participants was 20.7 years (SD = 4.32). Participants admitted to this study satisfied the following criteria:
(a) Gambled more than once per month on an Electronic Gaming Machine (EGM);
(b) Consumes at least three, but no more than 10, alcoholic beverages during a drinking session that occurred at least once per week during the past 6 months.

iii. Eighteen people recruited from the University of Western Sydney, Macarthur who met the above criteria. Participants were either employees of the University or first year students of the Faculty of Business. Six were female and 12 were male. The mean age was 22.56 years.

7.2.3 Materials
Pencil and paper questionnaire.

7.2.4 Procedure
The following procedure details that conducted by all three studies. Participants were seated and administered the SGC. It was explained to participants that there were two parts to the questionnaire. For the first part of the questionnaire, participants were instructed to circle the number above the word on each rating scale that best described how often that statement applied to them during the past 6 months. If a statement did not apply to them, participants were instructed to tick the box next to each rating scale. For the second part of the questionnaire, participants were instructed to circle the number above the word that best described how often they had actually experienced that statement in the past 6 months. If a statement did not apply to them, participants were instructed to tick the box next to each rating scale.

7.2.5 Results.
It was the hypothesis of this study that the SGC is composed of three factors as found by Baron, et al (1995). This hypothesis was not supported.

All of participants’ numerical responses to each of the statements of the questionnaire were collated and placed into one computer file made by the program SPSS Version 10. Data computation was conducted using this program.

Before analysis commenced, the distribution of scores was inspected via graphical analysis. Figure 1 displayed a distribution which approximated the normal ogive although slightly leptokurtic. Calculated skewness was .33 and kurtosis was -.171. The Kolmogorov – Smirnov (K.S) Z test yielded a coefficient of .921, p = .364. This suggests that the data satisfied the distributional assumptions of factor analysis. Data analysis followed Kline’s (1998,pp.62-64) “Criteria for sound factor analyses”. Hence a principal axis factor analysis procedure was undertaken with a Varimax orthogonal rotation procedure with Kaiser Normalisation.

![Total SGC score](image)

**Figure 1. Frequency histogram of the SGC total scores**

Inspection of the diagonal of anti-image correlation matrix revealed that the measures of sampling adequacy (MSA) yielded values greater than .81. Values approaching unity indicate that the variable was predicted with negligible error from the other variables, with factor analytic convention stating that values greater than .8 are ‘meritorious’ (Hair, Anderson, Tatham & Black, 1998, p.99). The Kaiser – Meyer – Olkin (KMO) test of
sampling adequacy yielded a value of .907. Bartlett’s Test of Sphericity gave \( \chi^2 (153) = 2224.27, p < .001 \), meaning that it was very highly probable that the correlation matrix displayed significant correlations among at least some of the variables (Hair, et al). All of the above analyses state that the variables were adequately selected and highly correlated enough for a factor analysis to be appropriately undertaken (Hair, et al).

An internal reliability test was undertaken using Cronbach’s alpha. The alpha coefficient had a value of .90 - indicating that the internal reliability of this scale is quite high. A test – retest reliability estimate was not available. Cronbach’s alpha, however, can be used instead of a test-retest correlation coefficient in such instances to compute the standard error of measurement (Traub & Rowley, 1991). The standard error of measurement was thus 4.1, the 95% true score C.I. was ± 7.95.

Analysis prior to rotation revealed 4 factors with eigenvalues greater than Kaiser’s criteria of 1 that cumulatively accounted for 60.97% of item variance. Only those factors with eigenvalues greater than 1 were selected for rotation. The loadings are presented in Table 1.

<table>
<thead>
<tr>
<th>Items</th>
<th>Factor I</th>
<th>Factor II</th>
<th>Factor III</th>
<th>Factor IV</th>
<th>( h^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
<td>.615</td>
<td>.357</td>
<td>.114</td>
<td>-.229</td>
<td>.571</td>
</tr>
<tr>
<td>Item 2</td>
<td>.613</td>
<td>.436</td>
<td>.280</td>
<td>-.211</td>
<td>.688</td>
</tr>
<tr>
<td>Item 3</td>
<td>.581</td>
<td>.207</td>
<td>.151</td>
<td>-.160</td>
<td>.429</td>
</tr>
<tr>
<td>Item 4</td>
<td>.570</td>
<td>.112</td>
<td>.155</td>
<td>-.0808</td>
<td>.368</td>
</tr>
<tr>
<td>Item 5</td>
<td>.372</td>
<td>-.182</td>
<td>.357</td>
<td>.102</td>
<td>.310</td>
</tr>
<tr>
<td>Item 6</td>
<td>.526</td>
<td>-.146</td>
<td>.334</td>
<td>.243</td>
<td>.469</td>
</tr>
<tr>
<td>Item 7</td>
<td>.606</td>
<td>-.295</td>
<td>-.119</td>
<td>.0505</td>
<td>.471</td>
</tr>
<tr>
<td>Item 8</td>
<td>.688</td>
<td>-.0073</td>
<td>.03</td>
<td>.019</td>
<td>.475</td>
</tr>
<tr>
<td>Item 9</td>
<td>.515</td>
<td>-.066</td>
<td>-.199</td>
<td>-.173</td>
<td>.339</td>
</tr>
<tr>
<td>Item 10</td>
<td>.550</td>
<td>-.236</td>
<td>-.202</td>
<td>-.085</td>
<td>.406</td>
</tr>
<tr>
<td>Item 11</td>
<td>.687</td>
<td>-.333</td>
<td>-.133</td>
<td>-.093</td>
<td>.609</td>
</tr>
<tr>
<td>Item 12</td>
<td>.732</td>
<td>-.332</td>
<td>.149</td>
<td>.047</td>
<td>.664</td>
</tr>
<tr>
<td>Item 13</td>
<td>.743</td>
<td>-.251</td>
<td>-.026</td>
<td>-.168</td>
<td>.644</td>
</tr>
<tr>
<td>Item 14</td>
<td>.316</td>
<td>.207</td>
<td>-.318</td>
<td>-.084</td>
<td>.251</td>
</tr>
<tr>
<td>Item 15</td>
<td>.565</td>
<td>.159</td>
<td>.033</td>
<td>.388</td>
<td>.496</td>
</tr>
<tr>
<td>Item 16</td>
<td>.630</td>
<td>.396</td>
<td>-.273</td>
<td>.165</td>
<td>.639</td>
</tr>
<tr>
<td>Item 17</td>
<td>.657</td>
<td>.082</td>
<td>-.343</td>
<td>-.097</td>
<td>.566</td>
</tr>
<tr>
<td>Item 18</td>
<td>.708</td>
<td>.02</td>
<td>.035</td>
<td>.345</td>
<td>.622</td>
</tr>
</tbody>
</table>

All the items loaded heavily, above the .3 level, onto the first factor. This may suggest that the SGC is a one-factor questionnaire, however, it accounted for only 38.97% of the variance. There was heavy substantial evidence of factors splitting after rotation. Items 1, 2, 5, 6, 11, 12, 14, 15, 16, 17 and 18 cross loaded. After rotation, the loadings of items 1, 2, 11, 12 and 16 were split across Factor 1 and Factor 2. Items 5, 6, 14 and 17 cross loaded onto Factor 3. Items 15 and 18 cross loaded onto Factor 4.
The results strongly suggest that the factor analysis was highly problematic and hence the hypothesis was not supported. No attempt was made at interpreting the factor analysis, except that the items appeared to load quite heavily onto Factor 1.

7.2.6 Discussion

It was hypothesised that the SGC would demonstrate a 3 factor structure as found by Baron et al (1995). This hypothesis was not supported.

The severe problem of cross loading of items means that the results of this study are very hard to interpret. The pattern of factor loadings before rotation suggest that the SGC has what is known as 1 factor simple structure. In the parlance of the factor analysts, the factor loadings of items indicates the presence of an unidimensional 'latent trait' of general choice/control over gambling. The amount of correlation variance accounted for by this one factor, however, was less than 40%. Typically, psychometric questionnaires that are purported as good should have their factor structures account for at least 70% of the correlation variance (Kline, 1998). The SGC in the present study failed to meet this minimum criterion. Hence in its present form, the SGC is an unsatisfactory 1 factor psychometric test.

Rotating the four factors that emerged with eigenvalues greater than one did not lead to an improvement of the results of the unrotated solution. Indeed it made them worse. Two factors (1 and 2) emerged with eigenvalues over 1 that cumulatively accounted for 42.4% of the data. Moreover, the items split into groups across the four factors as mentioned in the results.

It is typically assumed in psychometrics that the cross loading of items possibly indicates one or more of the three following problems. Firstly, the layout of items as they appear on the questionnaire may have been executed poorly. Thus the results of the factor analysis indicate that the layout of the questionnaire guided participants' responses and not the content of the items. This is known as the context variance problem and affects statements that have been constructed without formal attention being paid to the constituent predicates (Johnson, 2001). Secondly, that the written expression of the items themselves is very poor and thus the factor analysis indicates that participants may have been confused as to what some or all of the items meant. Thirdly, that the results of the factor analysis may indicate the presence of other hitherto undiscovered 'latent traits' influencing participants' responses. Factor analysis has no facility at all to indicate which of the three above problems is causing error in the results so, usually steps are taken to address all three problems at once.
Evidence for all three problems is present in the results of this study. That the first section of the questionnaire (which supposedly dealt with impulses to control to control gambling) split after rotation suggests that two ‘latent traits’ may have been present. Items 2 & 3 loaded only and strongly onto Factor 4, whilst items 5 and 6 did likewise with Factor 2; with item 4 cross loading weakly onto both factors. The former 2 items were, respectively, “I tried to spend less on my gambling” and “I tried to resist the opportunity to start gambling”. The semantic content of the predicates in these items may be interpreted as assessing actual attempts to resist impulses to gamble. Items 5 & 6 were, respectively, “I tried to limit the amount I gamble” and “I tried to stop gambling once I had reached self imposed limits”. The key predicate in both items can be interpreted as pertaining to actual attempts at limiting expenditure in gambling. The cross loading item 4 was worded “I tried to stop gambling for a period of time” and hence can be interpreted as either successfully resisting impulses to gamble or successfully stopping expenditure on gambling. In the parlance of classical test theory (Lord & Novick, 1968), this bisection of the items in the first part of the SGC into two groups across two factors may indicate the presence of two ‘latent traits’ – say, ‘ability to limit expenditure on gambling’ and ‘ability to resist impulses to gamble’. Thus the initial premise of the originators of the SGC (Baron et al, 1995) that all these items would strongly relate to each other in terms of attempts to control gambling may have been false. The results appear to suggest that participants’ responses were guided quite strongly by the semantic content of the predicates themselves rather than by their grouping into one section of the questionnaire. Participants appear to view the resistance of impulses to gamble and attempts to limit expenditure on gambling as two separate ‘latent’ factors of the ‘construct’ of choice/control. Item 4 may have cross loaded because its predicate was highly ambiguous.

Item 7 and items 9 to 13 loaded strongly onto Factor 1, with 7, 9 and 10 loading exclusive on this factor. Item 8 moderately loaded both onto Factor 1 & 2 and weakly loaded onto Factor 4. The loading of all of these items onto Factor 1 may have been due to the fact that they were all on the one page of the questionnaire. Hence the factor analysis indicated that the layout of the questionnaire might be poor and hence ‘Factor 1’ may have simply been an artifact of this poor design and was not a factor at all. The interesting item was number 8. It was worded “I’ve been able to stop easily after a few games or bets”. That this item loaded on Factor 2 with almost identical strength as it did on Factor 1 indicates that participants’ perceived this item’s semantic content as
pertaining to the limitation of expenditure on gambling. Items 11 and 13 also loaded weakly onto Factor 2 but strangely they were worded, respectively, “When I’ve wanted to I’ve been able to gamble less often” and “I’ve been able to gamble less often when I’ve wanted to”. These items are essentially the same hence the SGC possessed a degree of redundancy with these items.

Items 14 to 18 all loaded strongly onto Factor 3, with 14 being the item that loaded onto it solely. All of these items were again on the one page of the questionnaire hence ‘Factor 3’ may have been an artifact of poor questionnaire design like Factor 1. Factor 3, however, did not emerge after rotation possessing an eigenvalue over 1. This was probably due to the severe cross loading of items 15 to 18.

From the above it can be concluded that the layout of the items on the questionnaire exerted a strong influence over the rotated factor solution; with the semantic content of some of the items exerting a slightly smaller influence. Hence it can be safely interpreted that the SGC is a poorly designed questionnaire.

In defence of the present study, the participant sample was very heterogeneous and the participant – to – variable ratio was almost 16:1. Kline (1998) states these criteria must be satisfied if an acceptable factor analysis is to be conducted and indeed they were. The results of the KMO and Bartlett’s tests also support the view that the factor analysis was soundly conducted. The large magnitude of the internal reliability index (Cronbach’s alpha) suggested that the scale was internally valid.

There is, however, another factor that may explain the discrepancy between the results of this study and those of Baron et al (1995). In the parlance of the statisticians, the present study utilised only ‘convenience’ samples of participants. Conventional statistical wisdom states that such samples are problematic as participants may not be completely selected at random. As factor analysis is a statistical procedure and thus assumes the random sampling of participants, any violation of this assumption renders the application of the technique problematic. Hence the results of the present study. Baron et al used the much more sophisticated technique of a random, stratified ‘doornock’ survey which is much more likely to yield a fully random selection of participants than a convenience sample. Hence the results of their study are much stronger on sampling grounds than the results of the present study.

7.3 Study II: Further factor analytic and structural equation model (SEM) examination of the SGC.

7.3.1 Aims
There are two aims in this study. Firstly, to investigate further the factor structure of the Scale of Gambling Choices. It is hypothesised on the basis of the previous study, that a single one factor solution comprises the factorial structure of the Scale of Gambling Choices.

7.3.2 Design
Pencil and paper anonymous questionnaire design.

7.3.3 Materials
The 18 item version of the Scale of Gambling Choices (Baron, et al, 1995).

7.3.4 Participants
As per Chapter 5

7.3.5 Procedure
As per Chapter 5

7.3.6 Results
Before analysis was undertaken, missing values were calculated by the statistical software SPSS (Version 10). This was programmed to replace the missing values in each datum case by the mean of the nearby points for that item. The number of such points was set at 5. Thus that items were recalculated so as to include all participants in the final analysis. The total scores were subject to graphical analysis to assess their distribution (Fig. 2). This analysis displayed that the distribution very closely approximated a mesokurtic normal ogive. The skewness was -.249 and the kurtosis was -.532. The one – sample Kolmogorov – Smirnov test (K.S) yielded a coefficient of .853, \( p = .461 \), meaning that the distribution closely approximated the normal. These analyses suggested that the data could strongly meet the distributional assumptions of factor analysis.

A principle axes factor analysis with Direct Oblimin oblique rotation with Kaiser normalisation was performed. Delta was set at zero and kappa at four. Oblique rotation was employed as it was speculated that the Varimax orthogonal rotational procedure had split the items loadings across factors in the previous study. Such splitting could occur if the factors are correlated. For the original Baron , et al (1995) 18 item scale, the hypothesis was not supported. It was found that the obliquely rotated solution comprised of two factors. The factors and factor loadings are presented in Table 2.

Inspection of the anti – image correlation matrix revealed that 14 items had measures of sampling adequacy greater than .91. Three items had values greater than .85 and one item had a value of .75. These strongly suggest that the sampling of persons for each
item was good. The KMO measure of sampling adequacy yielded a value of .94. Bartlett’s Test of Sphericity gave $\chi^2 (153) = 3015.99, p < .001$. These indices suggest that sampling of the participant body was good.

Internal reliability of the scale was assessed via the calculation of Cronbach’s alpha, which was found to have a value of .93. This strongly suggests that the internal reliability of the scale is very good. The alpha value was used to calculate the standard error of measurement in the absence of a test-retest correlation coefficient (Traub & Rowley, 1991). The standard error of measurement was 5.1; the 95% true score C.I was ±9.98. In order to ascertain criterion validity, Pearson’s $r$ product moment correlations were conducted upon the total score, session expenditure and frequency of gambling play variables. Correlations of .26, $p < .01$ and .35, $p < .01$ were found between the total score and frequency of gambling play and within session expenditure, respectively.

![Histogram](image)

**Figure 2.** Frequency histogram analysis of the distribution of SGC total scores.

The Direct Oblimin rotation converged after 4 iterations and discovered two distinct factors, which were moderately correlated with a coefficient value of .39. The two factor simple structure solution accounted for 67.1% of item score variance. The pattern matrix (Table 2) shows that no items split to load across factors and all items bar Item 6
displayed loadings greater than .6, well above the standard .3 level. The first six items loaded heavily onto Factor II and Items 7 – 18 all loaded heavily onto Factor I. Factors I and II had initial eigenvalues of 9.24 and 2.83, respectively. These were much higher than Kaiser’s minimum criteria of 1.

The structure matrix (Table 3), however, suggested that the two factors discovered in the pattern matrix were not orthogonal, as evidence by the cross loadings of some, but not all, of the items. This lack of orthogonality suggests that the factors were indeed moderately correlated as suggested by the computed coefficient.

Table 2: Pattern Matrix and communalities (Oblimin rotation - pertinent factors are in bold print)

<table>
<thead>
<tr>
<th>Items</th>
<th>Factor I</th>
<th>Factor II</th>
<th>$\lambda^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
<td>.200</td>
<td>.711</td>
<td>.656</td>
</tr>
<tr>
<td>Item 2</td>
<td>.053</td>
<td>.826</td>
<td>.719</td>
</tr>
<tr>
<td>Item 3</td>
<td>.0084</td>
<td>.745</td>
<td>.561</td>
</tr>
<tr>
<td>Item 4</td>
<td>.160</td>
<td>.674</td>
<td>.564</td>
</tr>
<tr>
<td>Item 5</td>
<td>-.072</td>
<td>.780</td>
<td>.570</td>
</tr>
<tr>
<td>Item 6</td>
<td>-.088</td>
<td>.567</td>
<td>.291</td>
</tr>
<tr>
<td>Item 7</td>
<td>.785</td>
<td>-.038</td>
<td>.595</td>
</tr>
<tr>
<td>Item 8</td>
<td>.869</td>
<td>-.021</td>
<td>.741</td>
</tr>
<tr>
<td>Item 9</td>
<td>.872</td>
<td>-.118</td>
<td>.695</td>
</tr>
<tr>
<td>Item 10</td>
<td>.826</td>
<td>-.104</td>
<td>.627</td>
</tr>
<tr>
<td>Item 11</td>
<td>.933</td>
<td>-.033</td>
<td>.847</td>
</tr>
<tr>
<td>Item 12</td>
<td>.781</td>
<td>.021</td>
<td>.623</td>
</tr>
<tr>
<td>Item 13</td>
<td>.855</td>
<td>-.011</td>
<td>.724</td>
</tr>
<tr>
<td>Item 14</td>
<td>.864</td>
<td>-.047</td>
<td>.717</td>
</tr>
<tr>
<td>Item 15</td>
<td>.604</td>
<td>.148</td>
<td>.456</td>
</tr>
<tr>
<td>Item 16</td>
<td>.713</td>
<td>.207</td>
<td>.666</td>
</tr>
<tr>
<td>Item 17</td>
<td>.725</td>
<td>.097</td>
<td>.589</td>
</tr>
<tr>
<td>Item 18</td>
<td>.753</td>
<td>.162</td>
<td>.688</td>
</tr>
</tbody>
</table>

Table 3: Structure matrix (pertinent factors are in bold)

<table>
<thead>
<tr>
<th>Items</th>
<th>Factor I</th>
<th>Factor II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
<td>.475</td>
<td>.789</td>
</tr>
<tr>
<td>Item 2</td>
<td>.373</td>
<td>.846</td>
</tr>
<tr>
<td>Item 3</td>
<td>.297</td>
<td>.749</td>
</tr>
<tr>
<td>Item 4</td>
<td>.422</td>
<td>.736</td>
</tr>
<tr>
<td>Item 5</td>
<td>.230</td>
<td>.752</td>
</tr>
<tr>
<td>Item 6</td>
<td>.131</td>
<td>.533</td>
</tr>
<tr>
<td>Item 7</td>
<td>.770</td>
<td>.266</td>
</tr>
<tr>
<td>Item 8</td>
<td>.861</td>
<td>.315</td>
</tr>
<tr>
<td>Item 9</td>
<td>.826</td>
<td>.219</td>
</tr>
<tr>
<td>Item 10</td>
<td>.786</td>
<td>.216</td>
</tr>
<tr>
<td>Item 11</td>
<td>.920</td>
<td>.328</td>
</tr>
<tr>
<td>Item 12</td>
<td>.789</td>
<td>.323</td>
</tr>
<tr>
<td>Item 13</td>
<td>.851</td>
<td>.320</td>
</tr>
<tr>
<td>Item 14</td>
<td>.846</td>
<td>.287</td>
</tr>
<tr>
<td>Item 15</td>
<td>0.661</td>
<td>0.382</td>
</tr>
<tr>
<td>--------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>Item 16</td>
<td>0.794</td>
<td>0.483</td>
</tr>
<tr>
<td>Item 17</td>
<td>0.762</td>
<td>0.377</td>
</tr>
<tr>
<td>Item 18</td>
<td>0.816</td>
<td>0.454</td>
</tr>
</tbody>
</table>

To test the findings of the above exploratory solution a confirmatory factor analysis was undertaken using LISREL 8.30. The above data were fitted to a theoretical two-factor model confirmatory model. If the two factor exploratory solution found is the true factorial model underpinning the 18 item SGC then it will be supported by the theoretical model. The structural equation model did not support the exploratory factor solution (Tables 4 & 5).

The multiple squared correlations for each of the items is above .5, suggesting that each item is a good measure of the underlying latent trait. This is also supported by the ratios of the lambda estimates to the standard error of the lambda estimates. These ratios are much greater than the standard level of 2 hence they are further evidence in support of the items as good measures of the latent trait.

However, the fit indices in Table 5 show that the theoretical structural equation model was not a good fit to the observed data. The Chi-square value is large and significant, indicating that the overall fit of the model is very poor. The magnitude of this statistic, however, is easily exaggerated by a small number of estimated parameters and a large number of participants. Hence the calculation of the normed chi square, which divides the chi-square value by the degrees of freedom given by the number of estimated parameters. A value between 1 and 2 of this statistic indicates good fit of the model.

The value of four, however, far exceeds this standard. The other indices of absolute fit, the RMR, GFI and AGFI also fail to meet their respective standards. The incremental fit indices TLI and CFI likewise do not meet their respective standards. This evidence, whilst strongly supporting the measurement capacities of the items, rejects the two factor model discovered in the exploratory study.
Table 4: Parameter estimates for the LISREL model.

<table>
<thead>
<tr>
<th>Items</th>
<th>$\lambda_i$</th>
<th>SE</th>
<th>t - values</th>
<th>$\theta_i$</th>
<th>$R^2$</th>
<th>F.S.R*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
<td>.852</td>
<td>.057</td>
<td>15.019</td>
<td>.274</td>
<td>.726</td>
<td>.237</td>
</tr>
<tr>
<td>Item 2</td>
<td>.892</td>
<td>.055</td>
<td>16.169</td>
<td>.205</td>
<td>.795</td>
<td>.332</td>
</tr>
<tr>
<td>Item 4</td>
<td>.808</td>
<td>.058</td>
<td>13.845</td>
<td>.347</td>
<td>.653</td>
<td>.178</td>
</tr>
<tr>
<td>Item 5</td>
<td>.746</td>
<td>.061</td>
<td>12.329</td>
<td>.443</td>
<td>.557</td>
<td>.129</td>
</tr>
<tr>
<td>Item 6</td>
<td>.534</td>
<td>.066</td>
<td>8.05</td>
<td>.715</td>
<td>.285</td>
<td>.057</td>
</tr>
<tr>
<td>Item 7</td>
<td>.801</td>
<td>.058</td>
<td>13.922</td>
<td>.359</td>
<td>.641</td>
<td>.064</td>
</tr>
<tr>
<td>Item 8</td>
<td>.871</td>
<td>.055</td>
<td>15.876</td>
<td>.241</td>
<td>.759</td>
<td>.104</td>
</tr>
<tr>
<td>Item 9</td>
<td>.86</td>
<td>.055</td>
<td>15.547</td>
<td>.261</td>
<td>.739</td>
<td>.095</td>
</tr>
<tr>
<td>Item 10</td>
<td>.809</td>
<td>.057</td>
<td>14.135</td>
<td>.346</td>
<td>.654</td>
<td>.067</td>
</tr>
<tr>
<td>Item 11</td>
<td>.928</td>
<td>.052</td>
<td>17.697</td>
<td>.139</td>
<td>.861</td>
<td>.193</td>
</tr>
<tr>
<td>Item 12</td>
<td>.839</td>
<td>.056</td>
<td>14.967</td>
<td>.295</td>
<td>.705</td>
<td>.082</td>
</tr>
<tr>
<td>Item 13</td>
<td>.886</td>
<td>.054</td>
<td>16.319</td>
<td>.216</td>
<td>.784</td>
<td>.118</td>
</tr>
<tr>
<td>Item 14</td>
<td>.876</td>
<td>.055</td>
<td>16.024</td>
<td>.233</td>
<td>.767</td>
<td>.108</td>
</tr>
<tr>
<td>Item 15</td>
<td>.725</td>
<td>.060</td>
<td>12.088</td>
<td>.474</td>
<td>.526</td>
<td>.044</td>
</tr>
<tr>
<td>Item 16</td>
<td>.844</td>
<td>.056</td>
<td>15.083</td>
<td>.288</td>
<td>.712</td>
<td>.084</td>
</tr>
<tr>
<td>Item 17</td>
<td>.809</td>
<td>.057</td>
<td>14.140</td>
<td>.346</td>
<td>.654</td>
<td>.067</td>
</tr>
<tr>
<td>Item 18</td>
<td>.856</td>
<td>.055</td>
<td>15.441</td>
<td>.267</td>
<td>.733</td>
<td>.092</td>
</tr>
</tbody>
</table>

* F.S.R. = Factor score regressions, or loadings, each item had onto its theoretical exogenous variable or factor.

Table 5: Fit indices of the LISREL model

<table>
<thead>
<tr>
<th>Goodness – of – Fit Measures</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi – square</td>
<td>537.664</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>134</td>
</tr>
<tr>
<td>Probability</td>
<td>0.000</td>
</tr>
<tr>
<td>Normed Chi – square ($\chi^2 + df$)</td>
<td>4.01</td>
</tr>
<tr>
<td>Goodness of fit index (GFI)</td>
<td>.772</td>
</tr>
<tr>
<td>Adjusted goodness of fit index (AGFI)</td>
<td>.709</td>
</tr>
<tr>
<td>Comparative Fit Index (CFI)</td>
<td>.89</td>
</tr>
<tr>
<td>Tucker – Lewis Index (TLI)</td>
<td>.874</td>
</tr>
<tr>
<td>Root mean square residual (RMR)</td>
<td>.0628</td>
</tr>
<tr>
<td>Akaike Information Criterion (AIC)</td>
<td>629.569</td>
</tr>
<tr>
<td>Consistent Akaike Information Criterion (CAIC)</td>
<td>790.439</td>
</tr>
</tbody>
</table>

In addition to $R^2$, structural equation modelling allows for the calculation of two other reliability indices from the parameters of the structural model. The first index is of construct reliability and is given by the equation:

$$\rho_n = \frac{(\sum \lambda_i)^2}{(\sum \lambda_i)^2 + \sum \varepsilon_i}$$

(Fornell & Larker, 1981). The second reliability index is the variance extracted estimate. It is a more conservative index than the construct reliability coefficient and is given by the equation:

$$\rho_{v(\eta)} = \frac{\sum \lambda_i^2}{\sum \lambda_i^2 + \sum \varepsilon_i}$$
(Fornell & Larker, 1981). For the above structural equation model, $\rho_n = 0.97$ and $\rho_{\text{rel}(\eta)} = .68$. Thus according to the model, the SGC has a very high level of construct reliability. The more conservative value of the extracted variance estimate exceeds the conventional figure of .50, thus indicating that the observed variables are representative of the latent factors.

Structural equation models, however, do allow the re-specification of produced models in the light adverse findings via the calculation of modification indices, standardised residuals and critical ratios (t-values). As the critical values of each of the items were highly statistically significant in the above model, re-specification of the model followed standard LISREL practice of removing each item with a standardised covariance residual greater than 2.58 (Schumacker & Lomax, 1996) as such residuals are statistically significant at the .01 level. The removal of items 1, 4, 6, 7, 8, 15, 16 & 18 was executed in this manner, resulting in a structural equation model that fitted the data very closely. The results are presented below.

Table 6: Parameter estimates for the LISREL model.

<table>
<thead>
<tr>
<th>Items</th>
<th>$\lambda_i$</th>
<th>SE</th>
<th>$t$ - values</th>
<th>$\theta_i$</th>
<th>$R^2$</th>
<th>F.S.R*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 2</td>
<td>.922</td>
<td>.058</td>
<td>16.014</td>
<td>.150</td>
<td>.850</td>
<td>.617</td>
</tr>
<tr>
<td>Item 3</td>
<td>.803</td>
<td>.061</td>
<td>13.213</td>
<td>.356</td>
<td>.644</td>
<td>.226</td>
</tr>
<tr>
<td>Item 5</td>
<td>.751</td>
<td>.062</td>
<td>12.109</td>
<td>.437</td>
<td>.563</td>
<td>.172</td>
</tr>
<tr>
<td>Item 9</td>
<td>.821</td>
<td>.057</td>
<td>14.428</td>
<td>.325</td>
<td>.675</td>
<td>.094</td>
</tr>
<tr>
<td>Item 10</td>
<td>.810</td>
<td>.057</td>
<td>14.120</td>
<td>.344</td>
<td>.656</td>
<td>.087</td>
</tr>
<tr>
<td>Item 11</td>
<td>.946</td>
<td>.052</td>
<td>18.285</td>
<td>.104</td>
<td>.896</td>
<td>.337</td>
</tr>
<tr>
<td>Item 12</td>
<td>.858</td>
<td>.056</td>
<td>15.458</td>
<td>.264</td>
<td>.736</td>
<td>.121</td>
</tr>
<tr>
<td>Item 13</td>
<td>.903</td>
<td>.054</td>
<td>16.811</td>
<td>.185</td>
<td>.815</td>
<td>.181</td>
</tr>
<tr>
<td>Item 14</td>
<td>.899</td>
<td>.054</td>
<td>16.693</td>
<td>.192</td>
<td>.808</td>
<td>.174</td>
</tr>
<tr>
<td>Item 17</td>
<td>.798</td>
<td>.058</td>
<td>13.804</td>
<td>.364</td>
<td>.636</td>
<td>.081</td>
</tr>
</tbody>
</table>

* F.S.R. = Factor score regressions, or loadings, each item had onto its theoretical exogenous variable or factor.

Table 7: Fit indices of the LISREL model.

<table>
<thead>
<tr>
<th>Goodness - of - Fit Measures</th>
<th>Values</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi - square</td>
<td>54.039</td>
<td></td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Probability</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Normed Chi - square $\left(\chi^2 + df\right)$</td>
<td>1.60</td>
<td></td>
</tr>
<tr>
<td>Goodness of fit index (GFI)</td>
<td>.95</td>
<td></td>
</tr>
<tr>
<td>Adjusted goodness of fit index (AGFI)</td>
<td>.92</td>
<td></td>
</tr>
<tr>
<td>Comparative Fit Index (CFI)</td>
<td>.99</td>
<td></td>
</tr>
<tr>
<td>Tucker - Lewis Index (TLI)</td>
<td>.99</td>
<td></td>
</tr>
<tr>
<td>Root mean square residual (RMR)</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Akaike Information Criterion (AIC)</td>
<td>97.032</td>
<td></td>
</tr>
<tr>
<td>Consistent Akaike Information Criterion (CAIC)</td>
<td>188.321</td>
<td></td>
</tr>
</tbody>
</table>

Respecification allows the estimation of the ‘true’ model underpinning the data. The true model supports the findings of the exploratory factor analysis in that two factors
were found. Items 2, 3 and 5 loaded onto this factor which was titled ‘Attempts’. The rest of the items loaded onto another factor which was labelled ‘Control’; indicating a generic control factor. The model found a positive, moderate and highly significant phi parameter value between the two exogenous variables ($\phi = .43$, $S.E = .062$, $t = 6.838$). This supports the finding in the initial exploratory solution that the two factors were moderately, significantly correlated.

The above tables display two indices of model parsimony, the AIC and the CAIC. These indices are calculated using the following formulas: $AIC = \chi^2 + 2t$ and $CAIC = \chi^2 + (1 + \ln N)t$, where $t$ is the degrees of freedom of the model and $N$ is the sample size, $\ln N$ being the natural log of the sample size. Following LISREL convention, the model with the least AIC and CAIC values is the most parsimonious fitting model. Given the huge discrepancy in magnitude these indices displayed between the initial and respecified models, the latter was taken to be the most parsimonious, and hence the ‘true’, model.

The construct reliability and extracted variance estimate indices for the respecified model were, respectively, .96 and .73. The values of the indices suggest that the respecified model maintained a high level of construct reliability, whilst the extracted variance was slightly higher in the respecified model than in the original.

Although still statistically significant at the $\alpha = .05$ level, the chi-square was reduced in the respecified model to almost one – tenth of its original magnitude. An unfortunate problem is that the significance level of this statistic is greatly influenced by a large sample size. The sample participant size of the present study was 210 individuals. Sample sizes of approximately 200 observations or greater usually lead to significant chi-square values whilst sample sizes of approximately 100 or less usually lead to non-significant chi-square values (Schumacker & Lomax, 1996). The normed chi-square statistic was far below the maximum level of 3 for satisfactory fit, the GFI, AGFI and RMR also surpassed their respective standards of absolute model fit. Thus the respecified model fits the data well.

7.3.7 Discussion

The initial exploratory solution found that the questionnaire consisted of two factors. The second of these factors consisted of the items in Part One of questionnaire which was originally designed by Baron et al (1995) to differentiate between those gamblers who actually attempted to control their gambling versus those who did not attempt to do
so. After their analysis, Baron et al called this factor ‘frequency of intentions to limit gambling’.

The first of the factors found in the present study comprised of the remaining 12 items and formed Part Two of the questionnaire. This part of the questionnaire was originally intended to account for ‘failures to control gambling’, however, Baron et al found that this factor split up into two factors, one describing ‘ability to control gambling’ and ‘failure to control gambling’.

The results of the present study suggest that Baron et al’s original hypothesis concerning the factorial structure of the SGC was correct. In the present study, Part Two of the SGC loaded highly and significantly onto one factor. The confirmatory factor analysis structural equation model supported this interpretation, although in respecified form it supported the removal of 5 of the original 12 items of Part Two and 3 of the original 6 items of Part One, without affecting the reliability of the scale.

Two of the three remaining items of Part One, Items 2 and 5, pertained to the attempts at controlling expenditure on gambling. Specifically, these items assessed attempts to spend less on gambling and attempts to limiting the amount spent gambling within a session, respectively. The other remaining item of Part One was Item 3, which pertained to attempts to resist the opportunity to commence gambling activity. An interpretation that could be made here is that gamblers attempt to resist opportunities to start gambling in order to either completely stop their expenditure on gambling or to limit it their expenditure somewhat. Hence rather than label this factor as Baron et al (1995) did as ‘frequency of intentions to limit gambling’, the results of the present study suggest that the factor be re-labelled as ‘attempts to control gambling expenditure’.

Seven of the remaining 12 items of Part Two, Items 9, 10, 11, 12, 13, 14 & 17 were more heterogeneous in meaning than the items of Part One and suggested the presence of a more general underlying factor. These remaining items seemed to cover three different themes – the ability to cease gambling behaviour at will, the capacity to gamble less frequently at will and the ability to resist urges or impulses to commence gambling activity. Thus this factor could be appropriately relabelled with the original Baron et al term ‘failures to control gambling’.

There were aspects of the present study that precluded excessive identification of the results with Baron et al’s original speculations. The differences found in the factorial solutions between the two studies could have been due to the aforementioned difference in sampling procedure. Baron et al employed the statistically laudable procedure of a
random, stratified door-knock technique whilst the present study relied on convenience sampling. The factorial solution of the present study, however, accounted for more item score variance than did the original Baron et al study. This could be explained by the fact that the present study followed the suggestion of Kline (1998) in recruiting a very heterogeneous participant sample. The present study must have contained in its participant sample a far greater proportion of problem gamblers. This would have introduced a greater degree of linearity to the data by introducing a greater range of more extreme scores. This may have enabled the present study to account for greater item score variance than in the original Baron et al (1995) study.

Furthermore, the participant-to-variable ratio of the present study was over 11:1—surpassing the minimum ‘rule-of-thumb’ criteria of 10:1 (Kline, 1998). The results of the Msa’s, the KMO and Bartlett’s test also supported the view that the factor analysis was soundly conducted as the variables were strongly and adequately correlated. The large magnitude of the internal reliability index (Cronbach’s alpha) suggested that the scale was internally valid and hence that the standard error of measurement (Lord & Novick, 1968, Traub & Rowley, 1991) was very low.

As shown by the difference between the structure and pattern matrices of Tables 2 & 3, the factors found in the present study were moderately, positively correlated. This finding was further supported in the respecified structural equation model by the highly significant, moderate correlation coefficient found between the factors. This finding can be interpreted in two ways. Firstly, that there is an element of redundancy in the factorial solution. This might be the case, however, the factorial structure was tested using the structural equation model. It is unlikely that if there was high degree of redundancy between the two factors that the respecified or even initial structural model would have supported the presence of two exogenous constructs.

Secondly, that such a correlation is to be expected. It could be that as gamblers experience greater difficulty in controlling their gambling behaviour, they also increase their attempts to try to limit the amount of money they spend on gambling. This is the most plausible of the two explanations. Such an interpretation of the discovered relationship between the two factors also lends credence to the idea developed in Chapter 5 with the Subjective Control Scales that lower levels of subjective control are marked by conscious attempts at controlling one’s gambling. Gamblers who subjectively feel that they do not have complete control over their gambling feel the need to exercise conscious effort in order to control their gambling. This conclusion is further supported
by the finding in Chapter 5 of the significant and moderately positive correlation between the Subjective Control Scales and the SGC.

7.4 Study III: A reduced item variant of the Scale Of Gambling Choices – O’Connor’s (2001) 12 item version

Having examined the factorial structure of the 18 item questionnaire, attention was turned to the 12 item version of the SGC proposed and developed by O’Connor (2000). O’Connor argues, on the basis of his empirical work for his doctoral thesis, that the 12 item version forms a reliable measure of subjective control over gambling. O’Connor found that the simple structure obtained depended on the characteristics of the gamblers upon which the questionnaire was administered. With regular EGM gamblers, O’Connor found that the simple structure consisted of one factor. With on course bettors as participants, he found that the simple structure consisted of two factors. O’Connor suggested that the discrepancy between the exploratory factorial solutions was predicated somehow on the idiosyncrasies of the different types of gamblers. He did not, however, entertain the possibility that the effect may have been due to context variation. Nevertheless, O’Connor argued that the fewer number of items of this version meant that it is a more parsimonious scale than the original whilst not losing neither reliability nor validity. If this is the case, it would be certainly more attractive as a measurement apparatus than the original scale.

7.4.1 Design
Pencil and paper anonymous questionnaire design. O’Connor, however, changed the semantic categories and numerical markers of the Likert style ratings scales used with each item from those employed with the original 18 item scale. The categories consisted of ‘very rarely’, ‘rarely’, ‘sometimes’, ‘often’ and ‘very often’ which were scored 0, 1, 3, and 4, respectively.

7.4.2 Materials
The O’Connor 12 item version of the scale of Gambling Choices

7.4.3 Participants
As per Chapter 5

7.4.4 Procedure
As per Chapter 5

7.4.5 Results
Before analysis was undertaken, missing values were calculated by the statistical software SPSS (Version 10). This was programmed to replace the missing values in each
datum case by the mean of the nearby points for that item. The number of such points was set at 5. Thus that items were recalculated so as to include all participants in the final analysis. The distribution of total scores was assessed graphically using a frequency histogram (Fig. 3). Figure 3 shows that the distribution deviated greatly from the normal ogive in that it was highly positively skewed. The calculated skewness was .859 and the kurtosis was -.517. The Kolmogorov – Smirnov (KS) Z test gave a highly significant value of 2.39, \( p < .001 \), meaning that the distribution significantly departed from the normal. The standard statistical practice of performing a monotone transformation on the data to obtain normality, such as a natural or common logarithmic transformation, was negated due to the high number of zero total scores. Hence the assumption that the data met the distributional requirements of factor analysis was rendered problematic.

![Histogram](image)

Figure 3: Frequency histogram of the distribution of the O'Connor SGC total scores

A principle axes factor analysis with Direct Oblimin oblique rotation with Kaiser normalisation was performed. Delta was set at zero and kappa at four. Oblique rotation was employed because it was thought that if more than one factor emerged such factors would be highly correlated given the small number of items. Moreover, the items that loaded onto the second factor of the original scale were the items O'Connor removed from his version. Given that over 50% of the participants in this study nominated EGMs as their favourite form of gambling (see Chapter 5), it was hypothesised that a one factor 'unidimensional' simple exploratory structure would be obtained. This hypothesis was
not supported. It was found that the obliquely rotated solution comprised of two factors. The factors and factor loadings are presented in Table 8.

Inspection of the diagonal of the anti-image correlation matrix revealed that 10 items had measures of sampling adequacy greater than .9. The two remaining items had values of .896 and .891. These strongly suggest that the sampling of persons for each item was excellent and that the variables were sufficiently correlated with one another (Hair, et al, 1998). The KMO measure of sampling adequacy yielded a value of .93. Bartlett’s Test of Sphericity gave \( \chi^2 (66) = 2063.62, p < .001 \). These indices suggest that sampling of the participant body was sound.

Internal reliability of the scale was assessed via the calculation of Cronbach’s alpha, which was found to have a value of .95. This strongly suggests that the internal reliability of the scale is very good, better than the original Baron et al (1995) version. This is surprising as the magnitude of Cronbach’s coefficient is positively influenced by the number of items. The alpha value was used to calculate the standard error of measurement in the absence of a test-retest correlation coefficient (Traub & Rowley, 1991). The standard error of measurement was 2.9; the 95% true score C.I. was \( \pm 5.63 \).

In order to ascertain criterion validity, Pearson’s \( r \) product moment correlations were conducted upon the total score, session expenditure and frequency of gambling play variables. The respective correlations found were .30, \( p < .01 \) and .31, \( p < .01 \). These correlations suggest that the scale has low to moderate criterion validity.

The amount of item score variance accounted for by the two factor simple structure was 72.26% - a proportion of accounted variance greater than that found in the 18 – item version. This proportion also exceeds Kline’s (1998) minimum standard of 70% of accounted variance for well-constructed psychometric apparatus. The initial eigenvalues of these factors were 7.65 and 1.02.

The Direct Oblimin rotation (convergent after 5 iterations), however, found a strong correlation between the two factors of .76. This is problematic as it indicates possible redundancy or strong error effects. This is further indicated by the massive discrepancy between the pattern and structure matrices, all items loading very highly in the latter on both factors. Inspection of the item layout of the questionnaire with respect to the factor loadings depicted in Table 8 found that Items 1, 2, 7 and 10 were the only items not reversed scored. Thus the loadings upon factor two strongly appear only to be an artefact of item presentation. This means that either factor does not have a substantive /
theoretical base at all or that there is only one underlying factor. The latter interpretation the structure matrix supports. It may also indicate that the either the presence of these items in the factor analysis or their semantic content is problematic.

Table 8: Pattern Matrix and communalities of the O’Connor SGC (pertinent loadings in bold)

<table>
<thead>
<tr>
<th>Items</th>
<th>Factor I</th>
<th>Factor II</th>
<th>$h^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
<td>-.094</td>
<td>.982</td>
<td>.833</td>
</tr>
<tr>
<td>Item 2</td>
<td>-.0063</td>
<td>.898</td>
<td>.799</td>
</tr>
<tr>
<td>Item 3</td>
<td>.758</td>
<td>.046</td>
<td>.629</td>
</tr>
<tr>
<td>Item 4</td>
<td>.837</td>
<td>.052</td>
<td>.770</td>
</tr>
<tr>
<td>Item 5</td>
<td>.861</td>
<td>-.018</td>
<td>.719</td>
</tr>
<tr>
<td>Item 6</td>
<td>.759</td>
<td>.091</td>
<td>.689</td>
</tr>
<tr>
<td>Item 7</td>
<td>.234</td>
<td>.598</td>
<td>.626</td>
</tr>
<tr>
<td>Item 8</td>
<td>.858</td>
<td>-.065</td>
<td>.657</td>
</tr>
<tr>
<td>Item 9</td>
<td>.860</td>
<td>-.074</td>
<td>.648</td>
</tr>
<tr>
<td>Item 10</td>
<td>.143</td>
<td>.556</td>
<td>.450</td>
</tr>
<tr>
<td>Item 11</td>
<td>.743</td>
<td>.012</td>
<td>.567</td>
</tr>
<tr>
<td>Item 12</td>
<td>.669</td>
<td>.191</td>
<td>.679</td>
</tr>
</tbody>
</table>

Table 9: Structure Matrix of the O’Connor SGC (pertinent loadings in bold)

<table>
<thead>
<tr>
<th>Items</th>
<th>Factor I</th>
<th>Factor II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
<td>.654</td>
<td>.910</td>
</tr>
<tr>
<td>Item 2</td>
<td>.678</td>
<td>.894</td>
</tr>
<tr>
<td>Item 3</td>
<td>.793</td>
<td>.623</td>
</tr>
<tr>
<td>Item 4</td>
<td>.877</td>
<td>.690</td>
</tr>
<tr>
<td>Item 5</td>
<td>.848</td>
<td>.639</td>
</tr>
<tr>
<td>Item 6</td>
<td>.828</td>
<td>.669</td>
</tr>
<tr>
<td>Item 7</td>
<td>.690</td>
<td>.776</td>
</tr>
<tr>
<td>Item 8</td>
<td>.809</td>
<td>.589</td>
</tr>
<tr>
<td>Item 9</td>
<td>.804</td>
<td>.581</td>
</tr>
<tr>
<td>Item 10</td>
<td>.566</td>
<td>.665</td>
</tr>
<tr>
<td>Item 11</td>
<td>.755</td>
<td>.578</td>
</tr>
<tr>
<td>Item 12</td>
<td>.814</td>
<td>.701</td>
</tr>
</tbody>
</table>

To further test the factorial structure of O’Connor’s (2000) version of the SGC, a confirmatory factor analysis was undertaken using LISREL 8.30. If the two factor exploratory solution found is the true factorial model underpinning the 18 item SGC then it will be supported by the theoretical model. The structural equation model did not support the exploratory factor solution.

Similar findings were discovered to that which was found in the LISREL analysis of the original 18 item scale. The items themselves displayed good measurement characteristics as given by the lambda parameter estimates, highly significant $t$ - values and the squared multiple correlations. However, the indices of both overall and incremental fit were very poor. The structural model based measures of reliability - the construct reliability coefficient and the extracted variance estimate - were calculated and yielded values of .98 and .77, respectively. The high magnitudes of these coefficients indicate that the questionnaire was highly reliable.
It appeared that the structural equation model had indeed detected the irregularity of the two factor exploratory model. Thus it supports the above conclusion that the exploratory simple factorial structure was problematic in regards to the second factor.

Table 5: Parameter estimates for the LISREL model

<table>
<thead>
<tr>
<th>Items</th>
<th>( \lambda_i )</th>
<th>SE</th>
<th>( t ) - values</th>
<th>( \theta_i )</th>
<th>( R^2 )</th>
<th>F.S.R*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
<td>.930</td>
<td>.053</td>
<td>17.629</td>
<td>.135</td>
<td>.865</td>
<td>.340</td>
</tr>
<tr>
<td>Item 2</td>
<td>.929</td>
<td>.053</td>
<td>17.58</td>
<td>.137</td>
<td>.863</td>
<td>.333</td>
</tr>
<tr>
<td>Item 3</td>
<td>.850</td>
<td>.056</td>
<td>15.267</td>
<td>.277</td>
<td>.723</td>
<td>.093</td>
</tr>
<tr>
<td>Item 4</td>
<td>.929</td>
<td>.052</td>
<td>17.717</td>
<td>.137</td>
<td>.863</td>
<td>.205</td>
</tr>
<tr>
<td>Item 5</td>
<td>.912</td>
<td>.053</td>
<td>17.166</td>
<td>.167</td>
<td>.833</td>
<td>.165</td>
</tr>
<tr>
<td>Item 6</td>
<td>.877</td>
<td>.055</td>
<td>16.048</td>
<td>.231</td>
<td>.769</td>
<td>.115</td>
</tr>
<tr>
<td>Item 7</td>
<td>.870</td>
<td>.055</td>
<td>15.748</td>
<td>.242</td>
<td>.758</td>
<td>.177</td>
</tr>
<tr>
<td>Item 8</td>
<td>.866</td>
<td>.055</td>
<td>15.71</td>
<td>.251</td>
<td>.749</td>
<td>.104</td>
</tr>
<tr>
<td>Item 9</td>
<td>.897</td>
<td>.054</td>
<td>16.658</td>
<td>.196</td>
<td>.804</td>
<td>.138</td>
</tr>
<tr>
<td>Item 10</td>
<td>.771</td>
<td>.059</td>
<td>13.085</td>
<td>.405</td>
<td>.595</td>
<td>.094</td>
</tr>
<tr>
<td>Item 11</td>
<td>.822</td>
<td>.057</td>
<td>14.491</td>
<td>.324</td>
<td>.865</td>
<td>.010</td>
</tr>
<tr>
<td>Item 12</td>
<td>.892</td>
<td>.054</td>
<td>16.504</td>
<td>.205</td>
<td>.795</td>
<td>.017</td>
</tr>
</tbody>
</table>

* F.S.R = Factor score regressions, or loadings, each item had onto its theoretical exogenous variable or factor.

Table 6: Fit indices of the LISREL model

<table>
<thead>
<tr>
<th>Goodness – of – Fit Measures</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi – square</td>
<td>422.771</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>53</td>
</tr>
<tr>
<td>Probability</td>
<td>0.0</td>
</tr>
<tr>
<td>Normed Chi – square ( (\chi^2 + df) )</td>
<td>7.98</td>
</tr>
<tr>
<td>Goodness of fit index (GFI)</td>
<td>.763</td>
</tr>
<tr>
<td>Adjusted goodness of fit index (AGFI)</td>
<td>.652</td>
</tr>
<tr>
<td>Comparative Fit Index (CFI)</td>
<td>.881</td>
</tr>
<tr>
<td>Tucker – Lewis Index (TLI)</td>
<td>.852</td>
</tr>
<tr>
<td>Root mean square residual (RMR)</td>
<td>.0425</td>
</tr>
<tr>
<td>Akaike Information Criteron (AIC)</td>
<td>438.777</td>
</tr>
<tr>
<td>Consistent Akaike Information Criterion (CAIC)</td>
<td>547.455</td>
</tr>
</tbody>
</table>

As the exploratory analysis enabled the identification of the problem with the second factor, it may be incorrect to establish that the exploratory analysis itself was problematic given the results of the structural equation model. It is possible that because it was known from the exploratory analysis that the second factor was problematic, it would have been empirically tenable to initially specify the structural equation model to ignore those items. Structural equation models, however, do allow the re-specification of produced models in the light adverse findings via the calculation of modification indices, standardised residuals and critical ratios (\( t \) – values). Thus the re-specification of the structural equation model was undertaken commencing with the removal of the second factor. As the critical values of each of the items were highly statistically significant in the above model, re-specification of the model followed standard LISREL practice of removing each item with a standardised covariance residual greater than 2.58 (Schumaker & Lomax, 1996). The removal of items 1, 2, 4, 5 & 12 was executed in this
manner, resulting in a structural equation model that fitted the data. The results are presented below.

Table 7: Parameter estimates for the LISREL model

<table>
<thead>
<tr>
<th>Items</th>
<th>( \lambda_i )</th>
<th>SE</th>
<th>( t )-values</th>
<th>( \theta_i )</th>
<th>( R^2 )</th>
<th>F.S.R*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 3</td>
<td>.856</td>
<td>.56</td>
<td>15.33</td>
<td>.267</td>
<td>.733</td>
<td>.164</td>
</tr>
<tr>
<td>Item 6</td>
<td>.898</td>
<td>.054</td>
<td>16.57</td>
<td>.194</td>
<td>.806</td>
<td>.236</td>
</tr>
<tr>
<td>Item 7</td>
<td>.747</td>
<td>.060</td>
<td>12.49</td>
<td>.442</td>
<td>.558</td>
<td>.087</td>
</tr>
<tr>
<td>Item 8</td>
<td>.898</td>
<td>.054</td>
<td>16.59</td>
<td>.193</td>
<td>.807</td>
<td>.238</td>
</tr>
<tr>
<td>Item 9</td>
<td>.875</td>
<td>.055</td>
<td>15.88</td>
<td>.234</td>
<td>.766</td>
<td>.191</td>
</tr>
<tr>
<td>Item 10</td>
<td>.706</td>
<td>.061</td>
<td>11.55</td>
<td>.502</td>
<td>.498</td>
<td>.072</td>
</tr>
</tbody>
</table>

*F.S.R. = Factor score regressions, or loadings, each item had onto its theoretical exogenous variable or factor.

Table 8: Fit indices of the LISREL model

<table>
<thead>
<tr>
<th>Goodness – of – Fit Measures</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi – square</td>
<td>38.92</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>14</td>
</tr>
<tr>
<td>Probability</td>
<td>0.0</td>
</tr>
<tr>
<td>Normed Chi – square ( \chi^2 + df )</td>
<td>2.78</td>
</tr>
<tr>
<td>Goodness of fit index (GFI)</td>
<td>.95</td>
</tr>
<tr>
<td>Adjusted goodness of fit index (AGFI)</td>
<td>.91</td>
</tr>
<tr>
<td>Comparative Fit Index (CFI)</td>
<td>.98</td>
</tr>
<tr>
<td>Tucker – Lewis Index (TLI)</td>
<td>.97</td>
</tr>
<tr>
<td>Root mean square residual (RMR)</td>
<td>.03</td>
</tr>
<tr>
<td>Akaike Information Criterion (AIC)</td>
<td>63.771</td>
</tr>
<tr>
<td>Consistent Akaike Information Criterion (CAIC)</td>
<td>124.630</td>
</tr>
</tbody>
</table>

Table 8 displays the discrepancy the model had between fit indices. The chi – square was greatly reduced in magnitude to less than one – eleventh of its original value yet it remained statistically significant. Taken at face – value, this indicates a bad overall fit, however, the chi – square statistic is greatly influenced by large sample sizes relative to the number of parameters estimated (Schumaker & Lomax, 1996). Hence the calculation of the normed chi-square, which in this instance yielded a value in the acceptable model fit range of 2 – 3.

The construct reliability coefficient and the extracted variance estimate were again calculated for the respecified structural equation model. These coefficients yielded values of .94 and .69, respectively. The values of these coefficients remaining at high levels indicated that the questionnaire was still highly reliable. The overall fit indices (GFI, AGFI, RMR) all surpass standard levels of acceptable fit, the GFI indicating good fit. The incremental indices (TLI, CFI) surpass the acceptable level of .95, indicating the possibility of a very good fit to the model. Thus the overall and incremental fit of the model may actually be acceptable, despite the significant chi-square value.
Importantly, Items 7 and 10 remained in the respecified model. These were two of the original four items which loaded onto the second factor found in the initial exploratory factor analysis solution. This may suggest that the respecified structural equation model supports the two factor solution obtained with the exploratory factor analysis. The factor score regressions (Table 7), however, for these two items are very low, suggesting that the above interpretation may be problematic.

7.4.6 Discussion

Analyses conducted on the O’Connor version of the SGC in this study were rendered problematic by the lack of normality found in the distribution of the total scores. Classical test theory (Proposition 7 above) assumes that participants’ total scores will be normally distributed in order to calculate participants’ true scores. If this assumption is violated, calculation of true scores cannot proceed. Furthermore, the basic factor analysis model (Equation 9 above) assumes that total scores are normally distributed in order to express each participant’s total score in standardised form. Standardised scores cannot be calculated if this assumption is violated; hence the factor analyses conducted in this study were rendered problematic.

Moreover, the participant sample employed in the present study was the same sample used in the study of the 18 item version. The total scores of the 18 item version were indeed normally distributed as found by graphical and non-parametric (Kolmogorov – Smirnov Z test) analyses. A high frequency of zero total scores was found in the present study – a replication of very similar results found by O’Connor (2000) in his separate analyses. This replication strongly suggested that the Likert (1932) response scale utilised by the 12 item version of the SGC does not function properly. It appears to misguide participants into giving zero total scores by scoring the semantic category “very rarely” as zero. Future empirical work on the 12 item version of the SGC should therefore employ a different form of Likert response scale, such as the one used with the original 18 item scale. Unfortunately, the discovery of the malfunctioning Likert scale necessitates a very cautious interpretation of the results of the present study.

Nevertheless, the initial exploratory analysis yielded a two factor solution. This supports the results found by O’Connor (2000) in his study using EGM gamblers. Only two items in O’Connor’s study, however, loaded onto the second factor and they were different to the items that loaded onto the second factor in the present study. These items were “I have been able to stop gambling before the venue closed” and “I have been able to stop gambling before getting into debt”. Oblique rotation in the O’Connor study found
that these items loaded very heavily onto this second factor, thus leading O'Connor to conclude that this second factor was a non-trivial finding.

The structure matrix of the oblique rotational procedure employed in the present study, however, differed greatly from the pattern matrix in that all items heavily loaded onto both factors. This suggested that both factors were highly correlated. Close inspection of the structure matrix detected that the four items loading upon the second factor were the only items not reverse-scored. Hence the factorial solution of the present study may have only been an artefact of the presentation of items rather than a true reduction of the rank of item score correlation matrix. This conclusion is further strengthened by the fact that O'Connor's version of the SGC is just Part Two of the original 18 item SGC with different Likert (1932) summated rating scales. In the previous analyses concerning the 18 item scale, Part Two did not fracture such that the non-reverse-scored items loaded onto their own factor. This perhaps suggests the presence of the severe problem of context variation with the SGC.

The exploratory solution, however, was supported in the respecified structural equation model. Only two of the original four non-reverse-scored items (Items 7 and 10) remained to load upon the second factor. The respective wordings of these items were 'Once I have started gambling I have an irresistible urge to continue' and 'Even for a single day I have found it difficult to resist gambling'. If it is dismissed that the factorial solution was the result of item presentation, it could be argued on the basis of the semantic content of Items 7 and 10 that these items did indeed load onto a non-trivial factor. This factor could be labelled 'Ability to control urges/impulses to gamble'. Such a conclusion could be further strengthened by the fact that Items 1 and 2 loaded onto this factor in the initial exploratory solution. The respective wordings of these items were 'I have found it difficult to limit how much I gamble' and 'When I have been near a club/hotel, TAB or casino I have found it difficult to resist gambling'.

This is quite a tenuous argument, however. As mentioned earlier, these items in the analyses of the original 18 item scale were not found to load upon such a factor, which is contrary to what would logically be expected if this factor was indeed non-trivial. Hence the most plausible interpretation was that this second factor found in the analyses of the 12 item version of the scale was due to the combined effects of item presentation, context variation and the aforementioned lack of normality in the total score distribution. It may have been the case that if these particular four items were reversed scored as the other items in the scale were, this factor may not have emanated.
Context variation may have manifested to produce the differences in the factorial solutions between the 18 and 12 item versions in that the original 18 item version had a six item Part One. The presence of this Part One in the original scale may have influenced participants' responses such that Part Two loaded onto one factor only. Conversely, the absence of this Part One in the 12 item version may have influenced participants' responses such that the second factor manifested. It is pertinent to conject that the change in context (as per the presence/absence of Part One) led to variation in participants' responses as all participants completed both the 12 and 18 item versions. The results of the analyses conducted on the 12 item version may have been different if both versions were administered to different participant samples.

7.5 Final conclusions and discussion.

The purpose of the above was to demonstrate the multivariate statistical technique of factor analysis by way of empirical example. The subjects of the factor analyses were the 18 and 12 item versions of the SGC. The SGC is a prime example of classical test theory psychometrics employing the matrix method of factor analysis to produce a measurement apparatus. Both versions of the SGC were used as tests of concurrent validity on the Subjective Control Scales proposed in Chapters 5 & 6. Hence it was important that both versions of the SGC were subject to factor analysis in this thesis.

An ancillary purpose was to demonstrate by way of empirical example the techniques of SEM and confirmatory factor analysis. Confirmatory factor analysis has been proposed as a method by which factor analyses could become more scientific, in the sense that something resembling the empirical testing of a priori hypotheses is undertaken. Confirmatory factor analysis using SEM, however, is limited in this respect by the fact that a confirmatory factor model is only a model that best fits the observed data. Any other particular SEM model may indeed be a better fit. Thus even by using the rather advanced techniques of SEM does classical test theory remain limited by the reliance on the sample. IRT suffers not this limitation via its ability to produce sample free person and item parameters, which is something SEM cannot separate out from the set of total scores any test produces.

In respect to the substantive area of subjective control in gambling behaviour, the empirical results of this chapter were mixed. It indeed appeared that the 18 item version of the SGC as proposed originally by Baron et al (1995) was the better version. The 12 item version as proposed by O'Connor (2000) produced a very highly skewed distribution of total scores; and in so doing replicated the very finding of O'Connor's
(2000). This greatly limited the scope of interpretation of the results of the factor analyses performed upon the apparatus; but it did suggest that the apparatus has the severe problem of not being able to produce a normal distribution of total scores.

The factor analysis conducted upon the original Baron et al version suggests substantively that the apparatus is measuring two separate dimensions. The strong loadings upon the first factor suggests a dimension of actual, conscious attempts to control gambling. The second factor is harder to interpret but it suggests that the apparatus is measuring a second dimension of ‘control of impulses to gamble’, or a broader dimension of ‘failure to control gambling’. However, the apparatus is limited by the conceptual approach it takes towards subjective control, in that it defines subjective control as a dispositional trait. The factor structure was also not supported by the confirmatory factor analysis, however, this was discussed previously.

A method by which the development of both versions of the SGC could be advanced is in the application of IRT and the abandonment of factor analysis. The response data elicited by the SGC is of the cumulative kind as the higher the total score the more of the property the test respondent is argued to possess. The SGC asks test subjects to make their responses to the summated rating scales paired with each item in the test. Therefore in this case the Rasch model for ordered response categories (Andrich, 1978) is the ideal IRT candidate. This IRT model could provide not only sample free person and item estimates, but it can also be used as a check on the functioning of both the individual items and the rating scales used to assess the items. This would be particularly valuable to the 12 item version as it has demonstrated a persistent failure to generate a normal distribution of total scores.

It is difficult to see how further factor analytic studies conducted upon the versions of the SGC could assist in their development. The results of the present study suggest that perhaps the basic underlying dimensions have been identified. That the total scores of both versions were strongly correlated with the person measurements of Chapter 5 and the person location estimates of Chapter 6 strongly supports the notion that an underlying dimension(s) of subjective control exist; and that the versions of the SGC, as they currently stand, are assessing them to a degree. What future research upon the versions of the SGC needs to execute is the assessment of each of the individual items. It also needs to examine which types of rating scale work best with the items. The most convenient and sophisticated method of achieving this is through the application of the principles of IRT.
References


Andrich, D; de Jong, J.H.A.L & Sheridan, B.E. (1997). Diagnostic opportunities with the Rasch model for ordered response categories. In J. Rost & R. Langeheine (Eds.), *Applications of latent trait and latent class models in the social sciences* (pp. 59-70), Munster/New York: Waxmann.


Sobell, M.B & Sobell, L.C (1995). Controlled drinking after 25 years: how important was the great debate? Addiction, 90, 1149-1153.

Sobell, L.C; Sobell, M.B & Christelman, W.C (1972). The myth of "one drink". Behaviour Research and Therapy, 10, 119-123.


Three Theories of Psychological Measurement in the Assessment of Subjective Control in Gambling Behaviour

Andrew Stuart Kyngdon

A thesis presented to the University of Western Sydney in fulfilment of the requirements for the degree of Doctor of Philosophy (Psychology)

December, 2002

© A. S. Kyngdon December 2002
PLEASE NOTE

The greatest amount of care has been taken while scanning this thesis,

and the best possible result has been obtained.
Don’t forget Arithmetick, for take my word for it, it may be of great service to you, and cannot hurt

Richard Kyngdon Snr to Dr Richard Kyngdon, M.D. Jnr,
24th October 1799
Acknowledgements

The undertaking of this thesis could not have been accomplished without the assistance and input of the following people.

My supervisors Professor Mark Dickerson and Associate Professor Joel Michell. Without these two gentlemen – scholars this thesis would not have been done. I thank Mark for his perseverance, his encouragement, his willingness to see the better side of myself, his trust in my decisions, his trademark sagacious advice and his unstinting support in funding my research, additional training and materials. I thank Joel for warmly introducing me to the community of like-minded doctoral students at the University of Sydney, his perseverance, his encouragement, his quiet and perspicacious advice, his astounding and knowledgeable mind, and for educating me in abstract measurement theory and psychometrics.

Mr Tony Lackey, Special Projects Manager at Panther’s World of Entertainment, for his crucial contribution of allowing the recruitment of participants on Panther’s premises. The professionalism and solid good will that Mr Lackey and Panther’s conveyed made the job much easier. I also thank my research assistant Ms Nicole Lees, whose smile and sense of humour were a welcome pleasure.

Professor Alex Blaszczynski & Liverpool Hospital; Ms Sandra Palavs & CCAS; Dr Michelle Gunner & St. Edmunds Private Hospital; Mr Michael Doyle & Cyrenian House; Ms Adele Rabay & Mission Australia Creditworthy; and Mr Matt Jessimer & North Sydney Gambling Counselling Service. I thank these people and organisations heartily for their crucial contribution of allowing the recruitment of participants. Their amazing goodwill and persistence was utterly invaluable.

I thank Mr Brian McMahon of ETC, UNSW, for his exemplary desktop publishing skills and assistance in the preparation of the final copy of this thesis.

And finally, I thank my siblings Craig, David, Justin, Yolande, Jason and Felicity Kyngdon and my parents Catherine and Stuart. Their constant support over the years has been tremendous. I thank my close mates Hamish Burchell, Jason Chavasse, Karim Najjarine and Peter Fadeyev for their constant support and for keeping me sane!
Statement of Authentication

The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material, either in whole or in part, for a degree at this or any other institution.

Andrew Kyngdon
### Table of Contents

List of Tables viii  
List of Figures x  
Abstract xii  

Part One: A Brief Overview of Three Mutually Exclusive Theories of Measurement and the Techniques of Measurement.  
Chapter 1: Measurement by Science: The Classical & Representational Theories of Measurement.  
1.1 - Aristotle 1  
1.2 - Euclid of Alexandria 5  
1.3 - Definition of the classical theory of measurement 8  
1.4 - The presence of the classical theory of measurement in the physical sciences 10  
1.5 - Additivity summarised: The axioms of Otto Hölder (1901) 12  
1.6 - Additivity generalised: The Archimedean ordered group of translations (Luce, 1987) 14  
1.7 - The real numbers as ratios and their properties 19  
1.8 - The representational theory of measurement 22  
1.9 - The real numbers not as ratios but as sets 23  
1.10 - The current paradigm of scientific measurement: Foundations of Measurement Vol.1 25  
1.11 - Problems and criticism of the representational theory of measurement 28  

Chapter 2: Measurement by Fiat: S.S. Stevens and the birth of Operational Psychological Measurement  
2.1 - Stevens' (1951) operational definition of measurement 32  
2.2 - The presence of the operational definition of measurement in psychology 34  
2.3 - Stevens' (1951) theory of scale types 35  
2.4 - The nominal scale 36  
2.5 - The ordinal scale 37  
2.6 - The interval scale 38  
2.7 - The ratio scale 39  
2.8 - Criticism of the theory of scale types 39  
2.9 - The theory of scale types representationalised – Louis Narens (1981a & b) 45  

Chapter 3: The Techniques of Scientific Measurement: N.R Campbell (1924) & Luce & Tukey (1961)  
3.1 - Fundamental measurement 50  
3.2 - Derived measurement 51  
3.3 - The theory of simultaneous, additive conjoint measurement (Krantz, et al, 1971) 52  
3.4 - Axiom 1: Weak Ordering 53  
3.5 - Axiom 2: Independence 54  
3.6 - Axiom 3: Thomsen condition 54  
3.7 - Axiom 4: Restricted Solvability / Solvability 56  
3.8 - Axiom 5: Archimedean axiom 57  
3.9 - Representation theorem 58  
3.10 - An application of conjoint measurement to a psychological attribute 59  

Part Two: The Psychological Attribute of Subjective Control and its Empirical Investigation Within the Context of Gambling Behaviour  
Chapter 4: The development of the concept of subjective control in addiction to alcohol and addiction to gambling  
4.1 - “Loss of Control” and the medicalisation of alcoholism 62  
4.2 - The disease theory of alcoholism: E.M Jellinek (1960) 64  
4.3 - Empirical rejection of the “loss of control” thesis 66  
4.4 - The Alcohol Dependence Syndrome (ADS) (Gross & Edwards, 1976) and the concept of “impaired control” 68  
4.5 - The ADS and “impaired control” as quantitative and measurable psychological phenomena 71  
4.6 - The introduction of classical test theory of psychometrics to “impaired control” – the factor analysing of the ADS 73  
4.7 - The first independent psychometric investigation of “impaired control” in alcoholism 79
<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>81</td>
</tr>
<tr>
<td>85</td>
</tr>
<tr>
<td>88</td>
</tr>
<tr>
<td>93</td>
</tr>
<tr>
<td>94</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>102</td>
</tr>
<tr>
<td>102</td>
</tr>
<tr>
<td>102</td>
</tr>
<tr>
<td>102</td>
</tr>
<tr>
<td>102</td>
</tr>
<tr>
<td>102</td>
</tr>
<tr>
<td>103</td>
</tr>
<tr>
<td>104</td>
</tr>
<tr>
<td>105</td>
</tr>
<tr>
<td>107</td>
</tr>
<tr>
<td>113</td>
</tr>
<tr>
<td>114</td>
</tr>
<tr>
<td>114</td>
</tr>
<tr>
<td>115</td>
</tr>
<tr>
<td>115</td>
</tr>
<tr>
<td>117</td>
</tr>
<tr>
<td>117</td>
</tr>
<tr>
<td>117</td>
</tr>
<tr>
<td>118</td>
</tr>
<tr>
<td>118</td>
</tr>
<tr>
<td>120</td>
</tr>
<tr>
<td>120</td>
</tr>
<tr>
<td>121</td>
</tr>
<tr>
<td>122</td>
</tr>
<tr>
<td>128</td>
</tr>
<tr>
<td>128</td>
</tr>
<tr>
<td>128</td>
</tr>
<tr>
<td>128</td>
</tr>
<tr>
<td>128</td>
</tr>
<tr>
<td>129</td>
</tr>
<tr>
<td>129</td>
</tr>
<tr>
<td>130</td>
</tr>
<tr>
<td>130</td>
</tr>
<tr>
<td>132</td>
</tr>
<tr>
<td>132</td>
</tr>
<tr>
<td>133</td>
</tr>
<tr>
<td>145</td>
</tr>
<tr>
<td>151</td>
</tr>
<tr>
<td>159</td>
</tr>
<tr>
<td>170</td>
</tr>
<tr>
<td>174</td>
</tr>
<tr>
<td>176</td>
</tr>
</tbody>
</table>
6.3 – The Rasch (1960) model as probabilistic conjoint measurement
6.4 – The simple and generalised hyperbolic cosine models of unidimensional unfolding
6.5 – The empirical test of the Subjective Control Scales via the family of probabilistic unfolding functions
6.5.1 – Aims
6.5.2 – Design
6.5.3 – Participants
6.5.4 – Materials
6.5.5 – Procedure
6.6 – Results
6.6.1 – Item locations & latitude of acceptance parameters of the rating scale model
6.6.2 – Criterion, concurrent & discriminative validity & internal reliability
6.6.3 – Item locations & tests of fit of the SHCM paired comparison model
6.7 – Comparisons of the ordered metric information between axiomatic and probabilistic scaling solutions
6.8 – Discussion and conclusions

Chapter 7: Final discussions and conclusions

References
Appendix 1 – Initial pilot testing of the Subjective Control questionnaires
Appendix 1a – The ordinal determinables, tree structure diagrams, predicates and constructed statements used in the initial pilot study
Appendix 2 – Secondary pilot testing of the revised subjective control scales
Appendix 3 – Final pilot testing of the revised Subjective Control scales
Appendix 4 – Rating scale item expectation curves for the statements of the Subjective Control scale of general control over gambling
Appendix 5 – Rating scale item expectation curves for the statements of the Subjective Control scale of control over time spent gambling
Appendix 6 – Rating scale item expectation curves for the statements of the Subjective Control scale of control over urges to gamble
Appendix 7 – Statement maps and person distributions of the rating scale models
Appendix 8 – Item probability graphs for the SHCM paired comparison model for the general version of the Subjective Control scales
Appendix 9 – Item probability graphs for the SHCM paired comparison model for the time involvement version of the Subjective Control scales
Appendix 10 – Item probability graphs for the SHCM paired comparison models for the impulses to gamble version of the Subjective Control scales
Appendix 11 – Person distributions for the HCM unfolding model for pairwise preferences
Appendix 12 – Scatterplots of the transformed Goode’s algorithm and SHCM pairwise preference statement location values
Appendix 12a – Curve fitting of the scatterplots of Appendix 12
Appendix 13 – Scatterplots of the transformed Goode’s algorithm and GHCM rating scale statement values
Appendix 13a – Curve fitting of the scatterplots of Appendix 13
Appendix 13b – Line fitting of log transformed GHCM statement locations
Appendix 14 – Reference list of physics monographs used in the library survey
Appendix 15 – Reference list of psychology monographs used in the library survey
Appendix 16: First Subjective Control Scale questionnaire booklet administered to all participants
Appendix 17: The SGC (Baron et al, 1995; O’Connor, 1995) questionnaire booklet. This version commenced with the Baron et al version; the other with the O’Connor.
Appendix 18: Retest phase Subjective Control Scale questionnaire booklet administered to participants.
Appendix 19: Correlation matrices of the rating scale data of the Subjective Control scales
Appendix 20: Exploratory and confirmatory factor analyses of the two versions of the Scale of Gambling Choices (Baron, Dickerson & Blaszczynski, 1995; O’Connor, 2000)
Appendix 12b: Line fitting of log transformed SHCM statement locations
List of Tables

5.1 Overall paired comparison error rates of the three versions of the Subjective Control scales. 134
5.2 Student—group pair comparison error rates of the three scale versions. 134
5.3 In situ club gambler—group pair comparison error rates of the three scale versions. 134
5.4 Self—referred problem gambler—group pair comparison error rates of the three scale versions. 134
5.5 Number of totally erroneous pair comparisons and number of successful / scale retrievals 134
5.6 Pearson's $r$ correlations between test and retest ratings data for each statement ($n = 210$). 146
5.7 Kendall's tau-b correlations between test and retest rank data for each statement ($n = 210$). 146
5.8 Kendall's tau correlations between pair comparison and ranking data (test phase) ($n = 210$). 147
5.9 Kendall's tau correlations between pair comparison and rank (retest phase) ($n = 210$). 147
5.10 Pearson's $r$ correlations between the test / scale values and frequency of gambling and session expenditure. 149
5.11 Pearson's $r$ correlations between the retest / scale values and frequency of gambling and session expenditure. 149
5.12 Pearson's $r$ correlations between the test / scale values and total scores of both versions of the SGC. 149
5.13 Pearson's $r$ correlations between the retest / scale values and total scores of both versions of the SGC. 149
5.14 / scale values in the problem gambler group with SOGS $> or = to 10$ ($n = 36$). 150
5.15 Factor loadings & communalities for the general version—test condition 155
5.16 Factor loadings & communalities for the general version—retest condition 155
5.17 Factor loadings & communalities for the time involvement version—test condition 156
5.18 Factor loadings & communalities for the time involvement version—retest condition 156
5.19 Factor loadings & communalities for the impulses to gamble version—test condition 157
5.20 Factor loadings & communalities for the impulses to gamble version—retest condition 158
6.1 Locations and latitude of acceptance parameter values of the SSLM (general version) 200
6.2 Locations and latitude of acceptance parameter values of the SSLM (general version, retest) 201
6.3 Locations and latitude of acceptance parameter values of the HCM (general version) 201
6.4 Locations and latitude of acceptance parameter values of the HCM (general version, retest) 201
6.5 Locations and latitude of acceptance parameter values of the PARELLA model (general version) 202
6.6 Locations and latitude of acceptance parameter values of the PARELLA model (general version, retest) 202
6.7 Locations and latitude of acceptance parameter values of the SSLM (time involvement version) 202
6.8 Locations and latitude of acceptance parameter values of the SSLM (time involvement version, retest) 203
6.9 Locations and latitude of acceptance parameter values of the HCM (time involvement version) 203
6.10 Locations and latitude of acceptance parameter values of the HCM (time involvement version) 203
6.11 Locations and latitude of acceptance parameter values of the SSLM (impulses version) 204
6.12 Locations and latitude of acceptance parameter values of the SSLM (impulses version, retest) 204
6.13 Locations and latitude of acceptance parameter values of the HCM (impulses version) 204
6.14 Locations and latitude of acceptance parameter values of the HCM (impulses version, retest) 205
6.15 Correlations between criterion variables and person estimates of the general version. 205
6.16 Correlations between criterion variables and person estimates of the time involvement version 206
6.17 Correlations between criterion variables and person estimates of the urges to gamble version 206
6.18 Mean group person location and PSI of the SSLM of the general version 207
6.19 Mean group person location and PSI of the SSLM of the general version (retest phase) 207
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.20 Mean group person location and PSI of the HCM of the general version</td>
<td>208</td>
</tr>
<tr>
<td>6.21 Mean group person location and PSI of the HCM of the general version (retest phase)</td>
<td>208</td>
</tr>
<tr>
<td>6.22 Mean group person location and PSI of the SSLM of the time involvement version</td>
<td>208</td>
</tr>
<tr>
<td>6.23 Mean group person location and PSI of the SSLM of the time involvement version (retest phase)</td>
<td>209</td>
</tr>
<tr>
<td>6.24 Mean group person location and PSI of the HCM of the time involvement version</td>
<td>209</td>
</tr>
<tr>
<td>6.25 Mean group person location and PSI of the HCM of the time involvement version (retest phase)</td>
<td>210</td>
</tr>
<tr>
<td>6.26 Mean group person location and PSI of the SSLM of the urges to gamble version</td>
<td>210</td>
</tr>
<tr>
<td>6.27 Mean group person location and PSI of the SSLM of the urges to gamble version (retest phase)</td>
<td>210</td>
</tr>
<tr>
<td>6.28 Mean group person location and PSI of the HCM of the urges to gamble version</td>
<td>211</td>
</tr>
<tr>
<td>6.29 Mean group person location and PSI of the SSLM of the urges to gamble version (retest phase)</td>
<td>211</td>
</tr>
<tr>
<td>6.30 Test and retest phase statement locations and standard errors (general version)</td>
<td>212</td>
</tr>
<tr>
<td>6.31 Overall and paired comparison tests of fit of the SHCM to the general version</td>
<td>213</td>
</tr>
<tr>
<td>6.32 Test and retest phase statement locations and standard errors (time involvement version)</td>
<td>213</td>
</tr>
<tr>
<td>6.33 Overall and paired comparison tests of fit of the SHCM to the time involvement version</td>
<td>214</td>
</tr>
<tr>
<td>6.34 Test and retest phase statement locations and standard errors (urges to gamble version)</td>
<td>214</td>
</tr>
<tr>
<td>6.35 Overall and paired choice tests of fit for Table 6.34 (test phase chi squares below diagonal)</td>
<td>215</td>
</tr>
<tr>
<td>6.36 Pearson’s $r$ correlations between criterion variables and SHCM person location estimates</td>
<td>215</td>
</tr>
<tr>
<td>6.37 Exponential curvilinear model statistics with the SHCM values as the dependent variable.</td>
<td>219</td>
</tr>
<tr>
<td>6.38 Exponential curvilinear model statistics with the GHCM values as the dependent variable.</td>
<td>220</td>
</tr>
<tr>
<td>6.39 Linear model statistics with the log transformed SHCM values as the dependent variable.</td>
<td>221</td>
</tr>
<tr>
<td>6.40 Linear model statistics with the log transformed GHCM values as the dependent variable</td>
<td>221</td>
</tr>
</tbody>
</table>
3.1 Two non-empty sets can form the set of Cartesian products of all ordered pairs \((a, w, \ldots, c, y)\).
3.2 Tests of independence upon C, A and X in a simple 3 x 3 matrix. Note that the pairs are ordered from least \((a, w)\) to the greatest \((c, y)\) as the arrows are directed from less to greater.
3.3 The six tests of double cancellation needed for any 3 x 3 conjoint matrix is order to satisfy the weak order, independence and double cancellation axioms of Krantz et al. (1971). Arrows are directed from less to greater. Open head arrows denote antecedent relations and the solid head arrows the consequent.
5.1 The unfolding of the \(I\) scale \(wxyz\) around \(a\)'s ideal point of preference, the ideal stimulus \(i_p\). Collection of all possible \(I\) scales can enable the recovery of the original qualitative \(J\) scale.
5.2 The partial order of the midpoints of the four stimuli of the qualitative \(J\) scale as given by the \(8\) scales.
5.3 A proximity graph for the eight transitive \(I\) scales given by the rank orders made by 25 people. The figures in parentheses are the frequencies of each \(I\) scale made by test subjects. The dominant path is shown by the arrows with the solid heads.
5.4 The binary tree diagram of the predicates used to construct statements 11 to 14. The symbol \(t_n\) depicts the terminal node of each branch.
5.5 Diagram of the binary tree structure of the predicates of the Subjective Control scale of control over time spent gambling. The letters represent the reworded statements analogous to those generated by the binary tree.
5.6 Diagram of the binary tree structure of the predicates of the Subjective Control scale of general control over gambling behaviour. The letters represent the reworded statements analogous to those generated by the binary tree.
5.7 Diagram of the binary tree structure of the predicates of the Subjective Control scale of control over urges to gamble. The letters represent the reworded statements analogous to those generated by the binary tree.
5.8 The dominant \(I\) scale path (open – headed arrows) as predicted by the ordinal determinable binary tree structures used in this thesis.
5.9 The scaling solution of statements predicted by the ordinal determinable binary tree structures used in this thesis. The solution was derived using Goode's (1964, cited in Coombs, 1964) minimum integer algorithm of statement midpoints.
5.10 The dominant \(I\) scale path found in the test data of the general version of the Subjective Control scales. Broken line arrows indicate relationships between dominant path \(I\) scales and those falling outside of the dominant path. Numbers in parentheses indicate the number of subjects making that transitive preference order.
5.11 The dominant \(I\) scale path as discovered in the retest data for the general scale version.
5.12 The dominant \(I\) scale path discovered in the test data from the Subjective Control scale of control over time spent gambling. Note the split in the lower part of the diagram indicating a partial order upon the interstimulus midpoints.
5.13 The dominant \(I\) scale path as discovered in the retest data of the time involvement scale version.
5.14 The dominant \(I\) scale path discovered in the test data of the Subjective Control scale of control over urges to gamble.
5.15 The dominant \(I\) scale path discovered in the retest data of the urges to gamble scale version.
5.16 Satisfactory tests of the double cancellation condition of axiomatic conjoint measurement (Luce & Tukey, 1964) upon the interstatement midpoint orders found in the unfolding data. These tables test the midpoint order displayed in Figure 5.19. Solid arrows indicate the antecedent relations. Open arrows the consequent relation.
5.17 Satisfactory tests of the double cancellation condition of axiomatic conjoint measurement (Luce & Tukey, 1964) upon the interstimulus midpoint orders found in the unfolding data. These tables test the midpoint order displayed in Figure 5.18. Solid arrows indicate the antecedent relations. Open arrows the consequent relation.
5.18 A minimum integer algorithm (Goode, 1964, cited in Coombs, 1964) scaling solution for the impulses scale version. It is also the solution for the time involvement version if the right – hand branch of the dominant path (Figs. 5.12) is chosen to order the midpoints.
5.19 A minimum integer algorithm (Goode, 1964, cited in Coombs, 1964) scaling solution for the impulses scale version. It is also the solution for the time involvement version if the left – hand branch of the dominant path (Figs. 5.12) is chosen to order the midpoints.
6.1 A generic graded response item with three categories
6.2 Scatter plot of the transformed Goode's algorithm and SHCM values for the general version of the Subjective Control Scales
6.3 Fitting of exponential curve (with constants) to the scatterplot depicted in Figure 6.2.
Abstract

Psychological attributes are predominantly assumed to be quantitative phenomena like mass, length and time. Rarely is this assumption put to the test. This thesis sought empirically to test this assumption with respect to one substantively important attribute from the fields of addiction to alcohol (Edwards & Gross, 1976) and addiction to gambling (Dickerson & Baron, 2000; Dickerson, 1991). The attribute was subjective, volitional control. Psychometric apparatus have been devised to assess subjective control only relatively recently (Baron, et al, 1995; Heather, Tebbut, Mattick & Zamir, 1993). These apparatus, however, have been developed through the exclusive use of the matrix method of factor analysis (Spearman, 1904). This method of scale construction has attracted strong criticism from psychometricians and mathematical psychologists (eg Kline, 1998; Michell, 1990, 1997b; Krantz, Luce, Suppes & Tversky, 1971) in that the procedure has no inherent facility to test the hypothesis that the attributes concerned are quantitative.

The aim of the present study was to argue for a new conception of subjective control and then to devise psychometric scales to test this new conception in the area of gambling behaviour. The ‘Subjective Control’ scales were constructed using Michell’s (1994a, 1998) theory of the ordinal determinable. After extensive pilot testing, these scales were administered to a participant sample consisting of 57 students, 104 in situ club EGM players and 49 self-referred problem gamblers. The data collected consisted of paired comparison judgements, ratings and rank orders. These data were assessed using Coombs’ (1964) theory of unidimensional unfolding. It was found the data satisfied the conditions of axiomatic conjoint measurement (Luce & Tukey, 1964). This finding was consistent with the hypothesis that the attribute of subjective control is quantitative. A scaling solution was derived for each version of the Subjective Control scales using Goode’s (cited in Coombs, 1964) minimum integer algorithm. The paired comparison and rating scale data were then subjected to analysis using the simple hyperbolic cosine model (SHCM, Andrich, 1988b, 1989) and the generalised unfolding model for polychotomous responses with the hyperbolic cosine operation function (GHCM, Luo, 1998, 2001), respectively. These models have been argued to be probabilistic, item response theory (IRT) models of unfolding (Andrich, 1996). In addition to scaling solutions being derived, the SHCM and GHCM yielded
results suggesting that the ‘Subjective Control’ scales were valid and reliable instruments of measurement.

The rating scale data were also subject to factor analysis via the method of principal components. It was found that the data gave rise to factorial solutions consisting of two orthogonal factors. This supported the findings of previous research (van Schuur & Kiers, 1994) with respect to the *extra factor phenomenon* (Coombs, 1964, 1975; Coombs & Kao, 1960). The finding was interpreted as suggesting that factor analysis has limited capacity to identify unidimensional psychological attributes.

The Goode’s algorithm scaling solutions for each of the Subjective Control scales were compared to the scaling solutions derived by the SHCM and GHCM models for each scale. Accordingly, all scaling solutions were subject to affine (linear) transformations such that each solution was expressed as a 0 – 100 interval scale. The transformed Goode’s solutions were plotted against the transformed SHCM solutions for each scale version. Preliminary graphical analysis found highly systematic and elegant curvilinear relationships between these solutions.

Curve estimation was then undertaken to assess the functional form of the curvilinear figures. Estimating with constants in the models, it was found that the exponential function fitted the curves very closely. It was concluded that this result was consistent with the hypothesis that both Coomb’s (1964) and Andrich’s (1988b, 1989) theories of unfolding enable the measurement of subjective control; albeit conceptualising the additive structure of subjective control in different ways. This difference was argued to reside in differing theoretical arguments concerning the underlying response process (viz., the single peaked preference function). The limitations of the findings were discussed and suggestions for future research were made.