The Processing of Pitch and Temporal Information in Relational Memory for Melodies

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A thesis submitted for the degree of Doctor of Philosophy
University of Western Sydney
March 2008
I hereby declare that this submission is my own work and, to the best of my knowledge, it contains no material previously published or written by another person, nor material which has been accepted for the award of any other degree or diploma at the University of Western Sydney, or any other educational institution, except where due acknowledgement is made in the thesis.

I also declare that the intellectual content of this thesis is the product of my own work, except to the extent that assistance from others in the project’s design and conception is acknowledged.

__________________________
Tim Byron
Acknowledgements

You would not currently be reading this thesis without the assistance of the following people, who provided wisdom, encouragement, generosity, insight, and motivation.

Thanks are very much due to my primary supervisor, Assistant Professor Catherine Stevens, has been unfailing in her dedication and commitment as a supervisor for close to four years, from the first days in which I was able to begin researching this thesis in earnest, to – especially - those dying days when the world seems surreal. The ways in which Kate has contributed to this thesis are boundless, but her patience, encouragement, motivational skills, intellectual curiosity, critical insight, good humour, astute observations, and her belief in me all come to mind. This thesis does not resemble the thesis proposal I submitted in late 2003, and I am eternally grateful to Kate for the knowledge, insight, patience and guidance she gave me as my initially incoherent ideas and fancies eventually got pruned away, leaving the shape of a coherent thesis. I honestly don’t believe that a better supervisor than Kate exists.

Secondarily, thanks are due to my associate supervisors, Doctor Agnes Petocz, and Doctor Barbara Tillmann, each of whom has provided me with much wisdom, insight, and encouragement. Agnes’ commitment to the importance of theory within psychology has not only had a positive effect on me and this thesis, but on many of her former students and colleagues who have been part of the environment at UWS and MARCS Auditory Laboratories. The combination of Agnes’ knowledge and sharp logical thinking has made this thesis theoretically tighter, more coherent and logical, even in the sections she did not actively contribute to, as the thought “what if Agnes reads this?” often led to better writing, theory, and logical flow. Barbara, despite usually not residing in the same country, has made several theoretical and empirical contributions to this thesis which have made this a stronger document; her sharp eye for experimental detail and experimental manipulations has increased the worth of the experiments conducted within this thesis, and has helped immensely with the interpretation of those experiments.
The support staff at MARCS have been extraordinarily gracious and helpful; their ability to make things run smoothly is a large and possibly underestimated part of what makes MARCS such a stimulating, rewarding, and pleasant environment. The support with lab set-up given to me by Colin Schoknecht and Johnson Chen has been tremendously helpful, as has the efforts of Karen McConachie, Mel Gallagher, Darlene Williams and Gail Charlton to keep things running smoothly in all manner of ways, and I would like to sincerely thank them for their time and effort. Mel Gallagher helped tremendously getting things organised at the end.

It is hard to thank an entire research institute, but I would like to thank MARCS Auditory Laboratories, in general, for existing. MARCS has provided an amazingly stimulating, rewarding, and pleasant environment for me, and their help with resources, equipment and travel funding has been very beneficial for me, and has enabled me to fly to conferences in Brisbane, Australia and Bologna, Italy in 2006 and in Cambridge, England in 2007; I received invaluable comments, suggestions and criticisms at these conferences which contributed to the thesis. Thanks go especially to those with whom I’ve shared postgraduate rooms over the years – Nan Xu, Jess Hartcher-O’Brien, Lidija Krebs-Lazendic, Benjawan Kasisopa, Shaun Halovic, Paul Mason, Graham Howard, Arman Abrahamyan, Nicole Lees, Jennifer Le, Natalie Hughes, Ben Morrison, and Robert Sazdov - for putting up with me.

The Music, Sound, and Action reading/writing group at MARCS has seen many early drafts of chapters in this thesis, and I would like to sincerely thank members of the MSA group – especially Doctor David Brennan, Professor Roger Dean, Doctor Freya Bailes, Arman Abrahamyan, and Doctor Stephen Malloch - for their time and effort in reading those early drafts, for the penetrating insight and eye for details that have improved this thesis, and for the hours of stimulating discussion I have been witnessed and been a part of over the years.

I would like to thank my proofreading squad, who have graciously given up some of their time over the Easter long weekend to detect the more pernicious typographical errors and departures from the APA manual that escaped my hopelessly-too-close-to-
it eyes. So cheers to Bronson ‘Participant BBH’ Harry, Jadey O’Regan, Erin Cvejic, Natalie Hughes, Dogu Erdener, and Arman Abrahamyan.

Thanks also go to the many participants in my experiments. This is doubly so for the musically trained participants who didn’t have to do the experiment to obtain course credit, and who were very generous with their time and effort.

I would also like to thank the other members of The Reservations, Lazy Susan, Sliced Bread, the Sharkalarms, and Tom Stone and the Soldiers of Fortune for playing music with me over the course of this thesis, and being understanding about the last 6 months.

I would also like to thank the following for employing me as a tutor or as a research assistant, after my APA scholarship came to expire, thus enabling me to eat while finishing the PhD: David Brennan, Kate Stevens, Agnes Petocz, and (sadly departed and much missed) Professor Jim McKnight.

I would sincerely like to thank Victoria Williamson from the University of York, in England, for many reasons; firstly, for being one of the few people who studies a topic which vaguely resembles mine, and the several interesting conversations and discussions which resulted from this; secondly, for the insight, advice and help she gave to me in reading chapters of this thesis; and thirdly, I would like to thank Victoria and her husband Ben for their graciousness and kindness as hosts when I visited the University of York.

I would also like to thank Doctor Steven Roodenrys of the University of Wollongong, with whom I completed my honours thesis in 2003. Without Steve, you would not be reading this thesis, as he introduced me to the delights of experiments in cognitive psychology and told me that Kate and MARCS existed when I showed a fascination with music cognition. I had originally not intended to study the interaction of verbal short term memory and long term memory (my honours topic) in this thesis, but somehow it ended up being a major part of this thesis, and I am grateful to Steve for the knowledge and insight I received from him at the University of Wollongong, as it
helped immensely in writing parts of this thesis which even vaguely echo my honours topic.

I would like to thank researchers who have visited MARCS Auditory Laboratories, such as Professors Caroline Palmer and Laurel Trainor, who have graciously given their time and provided stimulating intellectual discussions, and would also like to thank Professors Eric Clarke, Nicola Dibben, Alan Baddeley, and Graham Hitch for generously allowing me to present my work at their laboratories in York and Sheffield, and for the enjoyable and useful discussions of my work that resulted.

Much love to my family – Mum, Wayne, Dad, Gina, Brendan and Colum – who have been supportive and understanding.

Finally, all of my love and appreciation goes to Jadey O’Regan, who I met in the first year of this thesis. As our lives have become progressively more intertwined in that time, her unfailing belief in me and help and understanding has gotten me through rough patches, hard problems, low points; knowing her has made me a better person. I only hope to help her as she has helped me in the last few months when the dying days of her PhD roll around in 2010/2011.
Abstract

A series of experiments investigate the roles of relational coding and expectancy in memory for melodies. The focus on memory for melodies was motivated by an argument that research on the evolutionary psychology of music cognition would be improved by further research in this area. Melody length and the use of transposition were identified in a literature review as experimental variables with the potential to shed light on the cognitive mechanisms in memory for melodies; similarly, pitch interval magnitude (PIM), melodic contour, metre, and pulse were identified as musical attributes that appear to be processed by memory for melodies. It was concluded that neither previous models of verbal short term memory (vSTM) nor previous models of memory for melodies are unable to satisfactorily explain current findings on memory for melodies.

The model of relational memory for melodies that is developed here aims to explain findings from the memory for melodies literature. This model emphasises the relationship between: a) perceptual processes – specifically, a relational coding mechanism which encodes pitch and temporal information in a relational form; b) a short term store; and c) the redintegration of memory traces using schematic and veridical expectancies. The relational coding mechanism, which focuses on pitch and temporal accents (c.f., Jones, 1993), is assumed to be responsible for the salience of contour direction and note length, while the expectancy processes are assumed to be more responsible for the salience of increases in PIM or deviations from the temporal grid.

Using a melody discrimination task, with key transposition within-pairs, in which melody length was manipulated, Experiments 1a, 1b, and 2 investigated the assumption that contour would be more reliant on the relational coding mechanism and PIM would be more reliant on expectancy processes. Experiment 1a confirmed this hypothesis using 8 and 16 note folk melodies. Experiment 1b used the same stimuli as Experiment 1a, except that the within-pair order was reversed in order to reduce the influence of expectancy processes. As expected, while contour was still
salient under these conditions, PIM was not. Experiment 2 was similar to Experiment 1b, except that it avoided using the original melodies in same trials in order to specifically reduce the influence of veridical expectancy processes. This led to a floor effect. Overall, the results support the explanation of pitch processing in memory for melodies in the model.

Experiments 3 and 4 investigated the assumption in the model that temporal processing in memory for melodies was reliant on the relational coding mechanism. Experiment 3 found that, with key transposition within-pairs, there was little difference between pulse alterations (which deviate more from the temporal grid) and metre alterations (which lengthen the note more) in short melodies, but that pulse alterations were more salient than metre alterations in long melodies. Experiment 4 showed that, with tempo transposition within-pairs, metre alterations were more salient than pulse alterations in short melodies, but that there was no difference in salience in long melodies. That metre alterations are more salient than pulse alterations in Experiment 4 strongly suggests that there is relational coding of temporal information, and that this relational coding uses note length to determine the presence of accents, as the model predicts.

Experiments 5a and 5b, using a Garner interference task, transposition within-pairs, and manipulations of melody length, investigated the hypothesis derived from the model that pitch and temporal information would be integrated in the relational coding mechanism. Experiment 5b demonstrated an effect of Garner interference from pitch alterations on the discrimination of temporal alterations; Experiment 5a found a weaker effect of Garner interference from pitch alterations on the discrimination of temporal alterations. The presence of Garner interference in these tasks when there was transposition within melody pairs suggests that pitch and temporal information are integrated in the relational coding mechanism, as predicted in the model.

Seven experiments therefore provide support for the assumption that a relational coding mechanism and LTM expectancies play a role in the discrimination of melodies. This has implications for other areas of research in music cognition. Firstly, theories of the evolution of music must be able to explain why features of these processing mechanisms could have evolved. Secondly, research into acquired amusia
should have a greater focus on differences between perceptual, cognitive, and LTM processing. Thirdly, research into similarities between music processing and language processing would be improved by further research using PIM as a variable.
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CHAPTER 1

*Introduction*
1.1 A Justification of the Study of Memory for Melodies

The fundamental aim of this thesis is to increase our knowledge of memory for melodies. The great majority of research into memory for melodies has used melody discrimination tasks, where participants hear two melodies and indicate whether those melodies are the same or different. Such research has shown, for example, that melodic contour, often referred to as the ups and downs of a melody (see Appendix A for further discussion of definitions of melodic contour), is salient in memory for melodies in the short term, and that tonality appears to be more important in the long term (e.g., Dowling, 1978).

This thesis will argue that the discussion of three particular controversies in the music processing literature would be benefited by further research into memory for melodies. Firstly, there has been much debate about the evolutionary emergence of music in human cultures (e.g., Fitch, 2006a, 2006b; Hauser & McDermott, 2005; Justus & Hutsler, 2005). Some of this research has suggested that the cognitive mechanism underlying memory for melodies may be an adaptation caused by natural selection. If this is so, further research into the cognitive mechanisms underlying memory for melodies will provide experimental evidence with which to evaluate these claims. Secondly, there has recently been some research investigating whether verbal short term memory processes music (e.g., Ockelford, 2007; Schendel & Palmer, 2007; Williamson, Baddeley, & Hitch, 2006). Research into the cognitive mechanisms underlying memory for melodies will provide better evidence by which to judge the possibility that memory for melodies is the result of similar cognitive mechanisms to those underlying verbal short term memory. Thirdly, there is controversy about the extent of modularity in music processing; some consider it to be highly modular (e.g., Peretz & Coltheart, 2003) while others consider it to be the likely result of general processes (e.g., Trehub & Hannon, 2006). The evidence for a modular conception of music processing is largely based on neuropsychological research involving people with acquired amusia; and most research into acquired amusia has used melody discrimination tasks; indeed many of the tasks in the Montreal Battery of Evaluation of Amusia (MBEA; Peretz, Chambod, & Hyde, 2003)
are melody discrimination tasks which can be taken to be measuring memory for melodies. Insofar that researchers interested in amusia are testing memory for melodies, further cognitive psychology research into memory for melodies may be informative about amusia, and thus may be informative in the debate between modular and general-process conceptions of music processing.

However, much of the research on memory for melodies was conducted in the period between 1971 (e.g., Dowling and Fujitani, 1971) and 1991 (e.g., Dowling, 1991; M. R. Jones & Ralston, 1991), and the period between 1991 and present has seen a smaller amount of research into this area (e.g., Dowling, Kwak, & Andrews, 1995; Halpern, Bartlett, & Dowling, 1995; Miyazaki, 2004). As such, this research has not been focused on current issues such as the role of short term memory in music and the presence of adaptations. Further cognitive psychology research into memory for melodies therefore has the potential to contribute to various theoretical debates occurring in the field of music cognition and music perception.

1.2 How this Thesis will Address these Issues

Chapter 2 will discuss research which deals with the possibility that the cognitive mechanisms underlying the human experience of music may be adaptations which are the result of natural selection. Section 2.3 will critically evaluate the various theories which have been used as a basis for claims that particular cognitive mechanisms are adaptations, while Section 2.4 will critically evaluate claims that particular aspects of music processing are the result of evolutionary adaptations; in particular, the possibility that cognitive mechanisms underlying memory for melodies are adaptations is discussed.

There will be a critical review of the wide range of experiments which can be regarded as experiments involving memory for melodies in Chapter 3. Section 3.2 will critically review research into memory for melodies, which largely involves melody discrimination tasks involving alterations to musical features such as melodic contour, interval, pitch interval magnitude (PIM; this is defined, after Stevens and Latimer, 1992, as the categorisation of pitch intervals into steps – intervals of around
3 semitones or less – and leaps – intervals of around 4 semitones and more), tonality, tempo, key, and note duration. Section 3.3 will critically review the literature on amusia, which also largely involves melody discrimination tasks involving alterations to musical features such as melodic contour, interval, PIM, metre, and rhythm. Section 3.4 will investigate neuroimaging research which has used tasks which may be considered to involve memory for melodies. In conclusion, Section 3.5 will suggest that further research on PIM, and on pulse and metre, and on the interaction between pitch information and durational information, will be useful in increasing knowledge about memory for melodies.

The evidence that similar cognitive mechanisms underlie memory for melodies and verbal short term memory (vSTM) will be reviewed in Chapter 4. Section 4.2 will first discuss similarities and differences between the tasks typically used in vSTM research and the tasks typically used in memory for melodies research; Section 4.3 will then discuss similarities and differences between the effects and findings in vSTM and memory for melodies. Section 4.4 will then assess the ability of various general models of vSTM to explain research findings from the memory for melodies literature, and Section 4.5 will assess the capabilities of models of music processing (e.g., Berz, 1995; Ockelford, 2007) to explain research findings from the memory for melodies literature. Section 4.6 will conclude that a new model of memory for melodies is necessary to account for the findings from the memory for melodies literature.

Chapter 5 will detail a cognitive model of relational memory for melodies. This model of relational memory for melodies is influenced by recent models of verbal working memory posited by Baddeley and colleagues (e.g., Baddeley, Gathercole, & Papagno, 1998). These models acknowledge the influence of perceptual processing and long term phonological memory on the workings of verbal short term memory. However, the model of relational memory for melodies detailed in this thesis instead emphasises the influence of perceptual processing and long term musical expectancies on the workings of memory for melodies. Sections 5.2-5.6 will detail aspects of the model, such as auditory memory, a relational coding mechanism, a short term store, and schematic and veridical expectancies. Section 5.8 will detail research questions which arise from the model which will be explored in Chapters 6 to 10.
Experiments 1a, 1b, and 2, which investigate the relative contribution of long term musical knowledge and perceptual processing to the discrimination of PIM (the steps and leaps in a melody), will be detailed in Chapters 6 and 7. In Experiment 1a, detailed in Section 6.2, participants with musical training and participants without musical training were asked to complete a melody discrimination task, with short and long folk melodies, and with alterations to contour, PIM, or both. Experiment 1b was similar to Experiment 1a, with one exception; in Experiment 1b, the melody alterations in different pairs occurred in the first melody in a pair rather than the second; this was considered to test the role of long term expectancies as participants heard each melody used several times in the experiment. Experiment 2, detailed in Chapter 7, resembled Experiment 1b, except that same melodies in Experiment 2 used the altered melodies from Experiment 1a rather than the same melodies in Experiment 1a.

The relative contribution of general time perception processes and the relational coding mechanism to memory for durational information in memories, specifically metre and pulse, will be investigated in Experiments 3 and 4, detailed in Chapters 8 and 9. In Experiment 3, detailed in Chapter 8, participants with musical training and participants without musical training were asked to complete a melody discrimination task, with short and long folk melodies transposed in key within-pairs, and with alterations to metre or pulse. Experiment 4, detailed in Chapter 9, resembled Experiment 3 with the exception that melodies were transposed in tempo within-pairs rather than transposed in key within-pairs.

Chapter 10 will detail Experiments 5a and 5b, which investigate the interaction between pitch information and duration information in order to investigate the relational coding mechanism. Both experiments used a Garner interference paradigm, which resembles a melody discrimination task except that there are additional alterations to other features of the melody which must be ignored. In Experiment 5a, detailed in Section 10.2, participants discriminated alterations to PIM and melodic contour, and were asked to ignore alterations to metre and pulse. In Experiment 5b, detailed in Section 10.3, participants discriminated alterations to metre and pulse, and were asked to ignore alterations to metre and pulse.
The thesis concludes with Chapter 11. Section 11.2 discusses the capacity of the model of relational memory for melodies to explain the results of Experiments 1a, 1b, 2, 3, 4, 5a and 5b, while Section 11.3 relates the results of the research to previous experiments. Section 11.4 details the implications of this thesis for the theoretical issues such as the extent of modularity in music processing, the likelihood that aspects of music processing are adaptations, and the relationship between vSTM and memory for melodies. Section 11.5 details future research suggested by the results of experiments and theory detailed in this thesis.
CHAPTER 2

*Human Memory for Melodies and Current Debates on the Evolutionary Emergence of Music*
2.1 Introduction

In this chapter the theoretical motivations behind the focus on relational memory for melodies in this thesis will be discussed, and will be linked to theoretical concepts and issues that are currently the source of intense debate in the study of music cognition. It will be argued in this chapter that one way of increasing knowledge of music cognition, given the current theoretical discussion of the evolution of music, is to increase our understanding of memory for melodies. *Homo Sapiens Sapiens* has been subject to natural selection; thus, music cognition in humans has also been subject to natural selection. It is currently unclear, however, whether the neural mechanisms involved in music cognition directly result from natural selection, or whether they are the by-product of natural selection for other neural mechanisms. The resolution of this question would greatly increase knowledge about music cognition.

However, this may not be a question that can be answered, at least at present. Section 2.3 argues that the different underlying theoretical assumptions in different theories of the evolution of human music are a result of the limits of human knowledge about evolutionary history, about the nature of music, and about the development and function of the brain. Given these difficulties, Section 2.4 evaluates several features of human music that have been argued to be the result of adaptations. Finally, Section 2.5 concludes with the argument that more cognitive psychology research about human cognitive mechanisms that may be evolved – in particular, memory for melodies – is necessary to increase knowledge about the ways in which music has been subject to evolution.

2.2 Music is a Result of Human Evolution, but is it an Adaptation Caused by Natural Selection?

Recently there has been much debate and speculation about the evolutionary emergence of music and its implications (e.g., Cross, 2006; Dean & Bailes, 2006; Driscoll, 2006; Fitch, 2006a, 2006b; Huron, 2006; Jackendoff & Lerdahl, 2006; Justus & Hutsler, 2005; Levitin, 2006; Livingstone & Thompson, 2006; McDermott &
Hauser, 2005; Merker, 2005, 2006; Mithen, 2005; Patel, 2006; Patel, Iversen, Chen, & Repp, 2005; Trainor, 2006; Trehub & Hannon, 2006). This debate and speculation has been motivated by the argument that, if music is a genetic adaptation, then research incorporating ideas about the evolutionary psychology of music will be useful in further illuminating the mechanisms that underlie the perception and production of music.

Amongst species most closely genetically related to humans (e.g., apes), music appears to be unique to humans. Although other ape species make music-like vocalisations – male and female gibbons who pair-bond and control a territory together sing ‘duets’ (Mithen, 2005), and bonobos call synchronously (Merker, 2000) – several features common to human music, such as recursive structure, melodic scales, rhythmic structure, and non-vocal instrumentation, appear to be absent in these species. Therefore, whatever capability humans have for music is most likely to have emerged in the period of time since the ancestors of modern human and chimpanzee species diverged (Mithen, 2005).

Although it is clear that humans are evolved creatures, it is not clear whether any of the cognitive and neural processes responsible for the human capability for music are adaptations directly caused by natural selection. Instead, this capability may piggyback on processes such as working memory and auditory perception, which evolved for reasons other than to assist humans perceive, cognise and produce music. As such, it is useful to determine which cognitive and neural processes are adaptations. However, there is controversy over how to determine whether particular cognitive and neural processes are adaptations caused by natural selection. Thus, it is necessary to discuss the different theoretical assumptions in theories of the evolution of music in humans, as different theories posit different criteria for determining whether cognitive and neural mechanisms are adaptations.
2.3 Theoretical Assumptions in Theories of the Evolution of Music Cognition in Humans

Three competing theories of the evolution of music in humans, each of which attempts to provide criteria for determining whether a neural mechanism is an adaptation, have been influential in recent discussions about the evolutionary emergence of music in humans (i.e., Justus & Hutsler, 2005; McDermott & Hauser, 2005; Jackendoff and Lerdahl, 2006). Determining which of these theories should be used in determining whether a neural mechanism is an adaptation is relevant to a discussion of the evolution of music cognition, as different theories with different criteria may suggest different neural mechanisms.

Theories which have been used to determine the role of evolution in the nature of music cognition are largely attempts to confront deficits in three crucial areas of knowledge. Firstly, little is known about the cortical development or structure of cognitive mechanisms implicated in human response to and production of music (see Section 2.3.1). Secondly, music from different cultures is profoundly different, leading to difficulties in even defining music, let alone identifying equivalent brain mechanisms in people from different cultures (Carterette & Kendall, 1999; Cross, 2003; Nettl, 2005; see Section 2.3.2). Thirdly, it is difficult to validate the inferences and assumptions that underlie the knowledge about the prehistory of the development of music (McDermott & Hauser, 2005; see Section 2.3.3). These discussions will illuminate Sections 2.3.4, which will analyse, in turn, the three competing theories in light of these methodological problems.

2.3.1 Difficulties in Knowing How the Brain Develops and Functions with Respect to Music

Knowledge of how neural development leads to music processing is crucial to any theory of evolutionary psychology, as natural selection works via the process of changing the proteins encoded by DNA; and proteins encoded by DNA direct neural development. Although the use of brain scanning technologies such as fMRI and
MEG has greatly increased knowledge of the cortical areas involved in different aspects of music processing (Peretz & Zatorre, 2005), there are limits to knowledge that can be gained by neuroimaging techniques (Coltheart, 2006a, 2006b). It is currently unknown, for example, whether processes in neural development can directly lead to the formation of complicated brain modules. Thus, theories that posit a modular model of music processing (Peretz & Coltheart, 2003) and theories that posit that a general *zygonic* process is responsible for the processing of melody, rhythm, timbre, pitch and metre (Ockelford, 2002) are equally plausible. This suggests that basic questions about how the human brain processes music have not yet been answered. In deciding that a neural mechanism is an adaptation, it would first be useful to know the processes involved in the development of that neural mechanism. However, because this knowledge is not readily accessible at present, theories of the evolutionary emergence of music must be based on assumptions about the extent of domain-specificity and the extent of modularity.

The extent to which these theories assume the brain is modular also influences whether theories overestimate or underestimate the amount of evolved mechanisms in the brain. Neural mechanisms must either be *adaptations* or *exaptations*; exaptations are evolutionary adaptive behaviours and structures that are not specified in the genome, but instead are alterations of the way existing adaptations are used. For example, our ability to read is an exaptation – it is adaptive in our current environment, but is unlikely to be specified in the genome, as the earliest recorded writing occurred relatively recently, in evolutionary terms. *Secondary adaptations*, according to Justus and Hutslcr (2005) involve the genetic alteration of an already exapted mechanism (e.g., if the throat is already being used for singing behaviour, changing the structure of the throat so that singing behaviour is less tiring or louder), so that it operates more efficiently. Theories that make an assumption that most of the brain is the result of adaptations for particular processes and modules (e.g., Peretz & Coltheart, 2003; Cosmides & Tooby, 1997) are more likely to incorrectly accept the hypothesis that a particular neural mechanism is an adaptation than theories that argue that most of the brain involves domain-general processes (e.g., Elman et al., 1996); conversely theories that argue that the brain largely consists of domain-general processes (e.g., Ockelford, 2002) are more likely to incorrectly reject the hypothesis that a particular neural mechanism is an adaptation. In summary, if a theory assumes
that neural mechanisms are typically modular, it may increase the likelihood of overestimating the amount of evolved mechanisms; if it assumes that neural mechanisms are typically non-modular, it may increase the likelihood of underestimating the amount of evolved mechanisms. Thus, until further is known about the extent of modularity in the brain, the extent to which these theories assume modularity cannot be used to determine whether a particular theory should be favoured over another in regards to which criteria they offer for determining whether a neural mechanism is an adaptation.

2.3.2 Difficulties in Knowing Evolutionary History

Cosmides and Tooby (1997) emphasise that for much of prehistory, humans evolved in an environment that differed from the current environment. Although the environment in which a trait evolved in most species is often similar to the current environment of that animal, humans appear to have adapted to a wide variety of environments by the use of culture and technology rather than by the alteration of genes. If the human use of music is the result of an adaptation, the way in which music is used in 2008 in Western culture is likely to have been different to how it was used on the African savannah around 100,000 BC – there is no archaeological evidence that prehistoric humans had iPods, for example. Thus, caution is needed when examining the current use of music in order to determine why a particular feature of music appears to be an adaptation.

However, barring the invention of a time machine, theories about the prehistory of music are at best educated speculation. Additionally, archaeological evidence is imperfect, containing assumptions and interpretations of ambiguous and indirect evidence (e.g., Mithen, 2005). Thus, it is difficult to know if evolutionary pressures have caused particular neural mechanisms involved in music to evolve. Because of this lack of knowledge, there is controversy about the use of evolutionary history in determining whether neural mechanisms are adaptations. Some theories place importance on a plausible evolutionary history of a neural mechanism (e.g., Cosmides & Tooby, 1997), while other theories avoid evolutionary history (e.g., Justus & Hutsler, 2005; McDermott & Hauser, 2005). Although evolutionary histories of music
are clearly speculative in nature – behaviour does not fossilise, and the first man to play music left no autobiography – the inclusion of informed, plausible speculation about the evolutionary emergence of music, based on the best available evidence, may be a useful and necessary part of a theory about the evolutionary emergence of music. A theory about the evolutionary history of music provides theoretical motivations for expecting adaptations in particular levels of cognitive domains, and thus provides a research agenda. For example, if the driving force behind music was that musical ability was sexually selected as an indicator of neural health (e.g., G. F. Miller, 2000), then one might expect gender differences in neural structures related to music. Thus, whether such gender differences exist would be an empirical question which has been theoretically motivated by evolutionary theory. However, a theory about the evolutionary history of music that is not clearly an attempt at providing a research agenda is in danger of being a just so story – a story about what might have happened that neatly explains a trait, but is unfalsifiable. Because of the difference between the current Western environment and the environment in which evolution may have occurred, and the paucity of archaeological data that is informative about musical behaviour (Mithen, 2005), theories of the evolutionary emergence of music are in danger of being just-so stories. Thus, theories of the evolutionary emergence of music have to make assumptions about how to best weight the importance of evolutionary history. Theories that privilege evolutionary history are in danger of being just-so stories based on inaccurate or misinterpreted information, whereas theories that attempt to ignore evolutionary history are not structured to encourage theories from which hypotheses might be deduced and then verified experimentally.

2.3.4 Theoretical Assumptions about the Evolutionary emergence of music Cognition

Sections 2.3.4, 2.3.5, and 2.3.6 will examine three theories – those of Justus and Hutslr (2005), Cosmides and Tooby (1997), and Hauser, Fitch, and colleagues (e.g., Hauser et al., 2002) respectively – that have been used by researchers attempting to determine the role of natural selection in the nature of music cognition. These sections will evaluate the suitability of these theories for determining whether neural mechanisms related to music are adaptations.
2.3.4.1 Justus and Hutsler

The theory posited by Justus and Hutsler (2005) combines an emphasis on domain-specificity with an emphasis on what is known about the physiological development of the human brain. For Justus and Hutsler, those neural and cognitive processes that are adaptations should firstly show signs of genetic constraints – that is, the presence of representational constraints (i.e., modules that are a direct result of an adaptation), architectural constraints (i.e., certain connections between neurons, kinds of neurons, or amount of neurons in a certain cortical area that are a direct result of an adaptation), or chronotopic constraints (i.e., the presence of a window of time where a gene can be expressed given a suitable environment). Secondly, according to Justus and Hutsler, these constraints should be specific to music.

Samuels (1998) argues, however, that the distinction between representational and architectural constraints used by Elman et al. (1996), from whom Justus and Hutsler (2005) have derived this aspect of their criteria, is false. Elman et al. (1996) argue that representational constraints are physiologically unlikely. However, Samuels (1998) argues that there is a continuum between representational and architectural constraints, and that simple architectural constraints can lead to what appear to be complex representational constraints. When Justus and Hutsler examine the evidence about the evolutionary emergence of music, they focus largely on cognitive processes (e.g., the perception of scale degrees) that a major theoretical basis of their theory (e.g., Elman et al., 1996) would consider to be the result of representational constraints, if they were the result of an adaptation. This may be due to the paucity of evidence about architectural constraints or critical periods related to music cognition (though see Russo, Windell, & Cuddy, 2003). Because Justus and Hutsler use a theoretical basis which argues that representational constraints are unlikely, it is not surprising that, when they analyse representational constraints, they do not find any evidence for music as an adaptation.

Though Justus and Hutsler (2005) argue that determining whether a cognitive structure or behaviour is domain-specific is important to determining whether it is an
adaptation, they do not properly delineate between different levels of domain-specificity, and do not define the term domain. This leads to significant problems for their theories. Elman et al. (1996) argue that domain-specificity may occur on five separate levels – that of tasks, behaviours, representations, processing mechanisms, or genes. The implication made by Elman et al. (1996) is that a particular behaviour, mental representation, processing mechanism or task may be a domain. Thus, although theorists often make the assumption that brain processing for a particular domain should be solely performed by processes devoted exclusively to that domain, it is often unclear what the theorists define that domain to be. As Justus and Hutsler largely focus on processing mechanisms such as the processing of melodic contour, or scale categories, they leave out many domains of music that may be specific – for example, the large amount of connections between brain areas that appear to be involved in the processing of music, and brain substrates involved in emotion and reward (Menon & Levitin, 2005) - and thus likely to be the result of constraints. It may be argued that this lack of insight is because they attempt to avoid the problems with evolutionary history, and thus cannot make specific predictions about what is likely to be an adaptation.

2.3.4.2 Cosmides and Tooby

A theory of the evolution of human neural mechanisms that has been influential in psychology is the evolutionary psychology paradigm developed by Cosmides and Tooby (e.g., Barkow, Tooby, & Cosmides, 1992; Cosmides & Tooby, 1997). Briefly, the principles of Cosmides and Tooby’ paradigm are: 1) that the brain is a computer designed to generate behaviour appropriate to environmental circumstances; 2) that the neural circuits of the brain have been designed by natural selection; 3) that much of this circuitry is not available to the conscious mind; 4) that different neural circuits are modular, meaning that they are specialised for a particular task; and 5) that it is plausible that these brain circuits evolved to deal with conditions in an African savannah (Cosmides & Tooby, 1997). According to Cosmides and Tooby (1997), if a neural mechanism can meet these criteria, it is likely to be evolved.
Pinker, Jackendoff, and colleagues (Jackendoff & Pinker, 2005; Pinker, 1993, 1997; Pinker & Jackendoff, 2005) have argued extensively that, given these criteria, the human faculty for language clearly appears to be an adaptation evolved due to natural selection, and that elements of speech perception and production, phonology, memory, and some concepts have been specifically evolved for language. Though Pinker (1997) is of the opinion that music is not an adaptation (see Section 2.5.1), Jackendoff & Lerdahl (2006) have attempted to use the criteria of Cosmides and Tooby (1997) to argue for music being an adaptation.

Because this theory of the evolution of cognitive processes is the oldest (e.g., Barkow, Tooby, & Cosmides, 1992) of the three mentioned here, most research in the field is based upon their criteria; thus there are several theories of the evolutionary emergence of music that postulate mechanisms in evolutionary history as having a causal effect on the evolutionary emergence of music (e.g., S. Brown, 2000; Cross, 2003; Dissanayake, 2000; Merker, 2000; G. F. Miller, 2000; G. F. Miller 2001; Mithen, 2005; see Appendix B for more information).

This theory is useful in leading to the formation of hypotheses, and it is not as reliant on the ability to establish that a module is domain-specific as the theory of Justus and Hutsler (2005). However, owing to the limitations in knowledge about human evolution, the theory of Cosmides and Tooby (1997) is problematic for several reasons. Because of its emphasis on the assumption of modularity, and conflicting evidence about whether this assumption is correct in regards to music cognition (e.g., Ockelford, 2002; Peretz & Coltheart, 2003), it may bias theorists towards incorrectly confirming hypotheses of modularity where modularity does not exist. Because of the emphasis on evolutionary history, the Cosmides and Tooby (1997) theory can lead to theories that are little more than just-so stories when not supported by rigorous empirical research, and because of our lack of knowledge of the prehistoric use of music, it is difficult to determine whether a particular explanation of the evolutionary development of music is accurate.
2.3.4.3 Hauser, Fitch, and colleagues

The theory proposed by Hauser, Fitch and colleagues (e.g., Fitch, 2006a, 2006b; Fitch, Hauser, & Chomsky, 2005; Hauser, Chomsky, & Fitch, 2002; McDermott & Hauser, 2005) posits that, to prove that a particular cognitive domain in humans is an adaptation, one must show that there are neural mechanisms or behaviours that are not present in other species, and that are necessary for the correct functioning of that domain. Thus, McDermott & Hauser (2005) argue that if a human neural mechanism involved in music cognition is found in other animals, then it is likely to be an innate property of the mammalian nervous system rather than the result of adaptations in the human genome specifically for that cognitive domain. This paradigm has the benefit, compared to the theory of Justus and Hutsler (2005), of not requiring domain-specificity to prove the presence of an adaptation, and it is biologically plausible, in that similar solutions, genetically, are often used by natural selection to adjust for similar environmental problems.

However, this theory is prone to three theoretical problems. Firstly, it cannot distinguish between neural mechanisms that are the result of an adaptation, and neural mechanisms that have been facilitated by an adaptation. In animal behaviour research, animals may take hours, days, or weeks to learn how to complete a task that humans can learn in minutes; for example, the rhesus monkeys capable of discriminating between melodic contours in the research by Wright, Rivera, Hulse, Shyan, & Neiworth (2000) had previously been “highly trained” with auditory stimuli, suggesting that it may not have been natural for them to discriminate between pitches. Thus, using such research to show that a particular processing mechanism must not be an adaptation is problematic, as the adaptation may be in facilitating the processing of such stimuli, not in enabling the processing of such stimuli. Secondly, and related to the first problem, it is problematic to assume that other species are like less developed versions of humans. A neural mechanism or behaviour being found in another species may be evidence that that ability is caused by the general properties of the mammalian or vertebrate nervous system. Fitch (2006a, 2006b) argues that because the mammalian nervous system is largely similar across mammals, similar solutions, genetically, may be used to solve similar problems in unrelated mammalian or vertebrate animals. However, Fitch’s argument is again based on assumption; that
homology is possible and perhaps likely in some cases does not preclude the possibility that a solution to an evolutionary problem is genetically analogous rather than homologous. The theory of Hauser, Fitch, and colleagues, as it is incapable of distinguishing between genetic homology and analogy, therefore predisposes the theory to incorrectly rejecting the possibility that a neural mechanism is an adaptation. Other species are as adapted to their own ecological niches as humans are to the various ecological niches that they occupy; chimpanzees did not stop evolving once their ancestors separated from the ancestors of humans. Despite their close genetic relationship to humans, they may have similar capabilities to those of humans which have evolved separately. Thus, unless it can be shown that most primates also share this ability, it may be that rhesus monkeys (e.g., Wright et al., 2000) have separately evolved a good perception of pitch for separate ecological reasons. Finally, as the theory ignores evolutionary history as a source of knowledge, and as it privileges domain-specificity and species-specificity, it is possible that, under this theory, abilities that are the result of culture rather than evolution, such as reading and writing, could be considered an adaptation, as they are domain-specific and species-specific.

2.3.5 Conclusions About Theoretical Assumptions About the Evolutionary Emergence of Music in Humans

In conclusion, the evidence for the likely path of the evolution of the human brain is inconclusive and largely based upon assumptions. Our knowledge about the specific presence and function of neural mechanisms is similarly inconclusive. For this reason, the three theories are all plausible, given the current state of knowledge about the development of the neural processes underlying the development of music cognition and the current state of knowledge about the way music is processed by the brain. The way to increase knowledge about the evolutionary emergence of music in humans is thus to increase knowledge about the neural processes underlying the development of music cognition and to increase knowledge about the way music is processed by the human brain; such an increase in knowledge will better inform these and future theories of the evolutionary emergence of music. Despite this scarcity of concrete evidence, the evolutionary status of music is important, as the experimental
hypotheses that result from the belief that music is the direct result of natural selection will differ from those that result from the belief that music is auditory cheesecake as far as evolution is concerned (e.g., Pinker, 1997).

There are theoretical problems with two of the theories, however, regarding the assumption of domain-specificity. Both Hauser et al. (2002) and Justus and Hutsler (2005) fail to define domain when discussing possible adaptations. This failure to define domain is problematic, as a variety of levels of an evolutionary problem could be considered a domain (A. Atkinson & Wheeler, 2004). Considering the objections of Sternberg (1989) and A. Atkinson and Wheeler (2004), who argue that domain-specificity does not exist under the strict definition of domain implied by Justus and Hutsler (2005), the criterion of domain-specificity is problematic for a theory of the evolutionary emergence of music. Additionally, the theory of Hauser, Fitch and colleagues has theoretical problems in that it emphasises species-specificity along with domain-specificity. These emphases mean that it is difficult for neural mechanisms that facilitate a cognitive domain to be accepted as an adaptation under their criteria; only neural mechanisms that enable the cognitive domain meet their criteria.

Instead of positing a set of criteria for determining whether something is an adaptation, it is better to be aware of the sources of knowledge in regards to evolutionary theory, and their limitations. In particular, little about the evolutionary history of music is known, and little about the development of the neural processes underlying music cognition is known. However, although little is known, this knowledge is important to a theory of music cognition, as the evolutionary status of music has important implications for understanding the way in which mechanisms in the brain are likely to function. Thus, with the current state of knowledge, such theories can be useful if they lead to research hypotheses which will increase our knowledge of the evolutionary emergence of music cognition.
2.4 Candidate Features of Music That May Have Been Contributed To By Evolution

Justus and Hutsler (2005) and McDermott and Hauser (2005) have recently discussed a number of features of music processing that may indicate the presence of an adaptation. Amongst those seen as most likely to be an adaptation by Justus and Hutsler (2005) are the neural correlates of scale categories, grouping and metre, and melodic contour; McDermott and Hauser (2005) come to similar conclusions. It is important to note, given the discussion of domains in Section 2.3.1, that these are not the only features of music that may be adaptations given a particular set of criteria; in particular, it has been argued that the way that music influences emotion and affect may be an adaptation (Jackendoff & Lerdahl, 2006; Livingstone & Thompson, 2006), and infants’ apparent interest in music may be an adaptation (Trehub & Hannon, 2006). However, this section will focus on the possible cognitive adaptations mentioned by Justus and Hutsler (2005) and McDermott and Hauser (2005). It should be pointed out that the divide between cognition and emotion is largely artificial, as it is likely that the neural mechanisms behind music cognition discussed in this thesis are present because they contribute to the relationship between music and emotion. However, topics such as infants’ motivation for listening to music (Trehub & Hannon, 2006), and the neural relationship between areas of the brain devoted to music cognition and areas devoted to affect (Menon & Levitin, 2005), deserve more space than they can be given in this thesis, and are largely beyond its scope.

2.4.1 Scale Categories

Justus and Hutsler (2005) argue that scale categories may be the result of a neural mechanism evolved specifically for that purpose. All cultures, including the Central Australian societies discussed by Will (1997), appear to use musical scales; Arom (2000) defines the use of musical scales as a crucial aspect of music, though these scales may vary in terms of amount of notes and frequency relationships between notes. Infants appear to attend to scales at early ages, and at 12 months appear to internalise a particular musical scale (Lynch, Short & Chua, 1995). This internalisation resembles the way that infants eventually internalise the phonemes
used in the languages used around them. Most empirical cognitive research comes from Western cultures that are comparatively more focused on pitch than cultures like the Ewe people of Ghana, who Pressing (1983) argues process rhythm in much the same way that Westerners process melody; pending future research with the Ewe people, it is possible that an adaptation for scale categories is actually an adaptation for discrete categories within a musical feature emphasised within a culture.

It has been argued that the cognition of pitch appears to involve, specifically, the right anterolateral part of Heschl’s gyrus (Peretz & Zatorre, 2005); this area presumably is involved in the mechanism underlying the perception of scale categories. That infants appear to internalise a scale, much as they internalise speech sounds, shows evidence of innate constraints. It is possible, however, considering the similar internalisation of speech sounds, that the internalisation of scale categories is an exaptation of a process designed by evolution for speech (Pinker, 1997) rather than an adaptation designed for music. Though it has been argued that interval information is specific to music, with no analogue in speech (Trainor, McDonald, & Alain, 2002), Mandarin speakers appear to use differences in the amount of change in fundamental frequency between tonal contrasts to distinguish between tones (Gandour, 1983).

Many theories of the evolutionary emergence of music may be able to explain the presence of scale categories. The use of discrete pitch sounds in music is a necessity for music to be recursive; these discrete pitch sounds could plausibly be at the level of a single pitch or at the level of a contour, but discrete pitch sounds at the level of a single pitch would presumably be more efficient. Recursiveness is required for the communication of complex emotional content (Huron, 2006; L. Meyer, 1956), and increases the efficiency of the communication (e.g., Hauser et al., 2002). S. Brown (2000) posits the existence of musilanguage,¹ a precursor of language, would explain the recursiveness of music as an adaptation designed to improve the communicative efficiency of musilanguage. Similarly, G. F. Miller (2000, 2001) and Dean, Byron, & Bailes (in press) have argued that music has been selected for because it is associated with other traits that are indicative of good genes, and thus are attractive to the opposite sex. If, as G. F. Miller has argued, the ability to handle the complexities of

¹ Mithen’s (2005) ‘hmmmm’ theory is similar to Brown’s (2005) musilanguage theory.
language (e.g., recursion) are indicative of useful brain traits (e.g., intelligence), and music shares this characteristic of language, the ability to understand or make music that features recursion may be an indicator of good genes.

In summary, there are plausible evolutionary mechanisms for explaining how musical scale categories came about, and it appears plausible that there are innate constraints that influence the development of scale categories. Thus, it is plausible that scale categories in music are an adaptation. However, more evidence is needed about the cross-cultural manifestation of scale categories, especially in cultures like that of the Ewe of Ghana. Additionally, cognitive and neuroscientific research would be informative as to the similarity between brain structures devoted to scale categories and brain structures devoted to pitch perception in speakers of tonal languages. Otherwise, it is also plausible that scale categories in music are a by-product of an adaptation designed to facilitate language.

2.4.2 Temporal Grouping and Metre

Justus and Hutsler (2005) nominate the neural mechanisms behind the perceptual processing of temporal grouping and metre as further candidates for innately constrained adapted neural mechanisms. Drake and Bertrand (2001) argue that five temporal processes are universal:

(i) “We tend to group into perceptual units events that have similar physical characteristics or that occur close in time” (Drake & Bertrand, 2001, p.24).

(ii) “We tend to hear as regular sequences that are not really regular” (2001, p. 25).

(iii) “We spontaneously search for temporal regularities and organise events around the perceived regularity” (2001, p.26).

(iv) “We process information best if it arrives at an intermediate rate” (2001, p. 27).

(v) We are predisposed to “hear a time interval as twice as long or short as previous intervals” (2001, p. 28).
However, despite their claims of universality, the paper by Drake & Bertrand (2001) is an attempt to provide clear hypotheses for researchers to test rather than a literature review; thus they mostly cite research with adult Western listeners, and cite little developmental research and no cross-cultural research to support their arguments. Nevertheless, there is some developmental evidence for the first of their five temporal processes - four and a half month olds orientated longer to pauses inserted within phrase boundaries than those inserted outside of phrase boundaries when listening to excerpts of Mozart minuets (Jusczyk & Krumhansl, 1993). Similarly, Trehub and Thorpe (1989) found that 7 to 9 month olds could categorise melodies on the basis of different rhythms, and that processing appeared to be relational rather than absolute, much like that of adults. However, Justus and Hutsler (2005) argue that grouping principles in music, especially in infant research, parallel grouping principles in language (e.g., Jusczyk & Krumhansl, 1993) and indeed parallel Gestalt principles in other perceptual domains (Bregman, 1990). If these grouping principles are basic perceptual processes, it makes it less likely that these are domain specific, or at least specialised for a domain.

Although the evidence that there is an adaptation for temporal grouping is slim, it is more plausible that there is an adaptation for the perception of what is called metre in Western music. In Western tonal music, metre is an underlying relational property of the temporal information in a piece of music that indicates the presence of some rule about the relationship between implied strong and weak beats in a piece of music. As a form of relational information that is implicit rather than explicit in a piece of music, the listener must construe the presence of metre based on implied cues in the music. Thus, the processing of metre appears to be a more complicated, relational, form of musical processing than the basic temporal grouping properties discussed by Drake and Bertrand (2001), and thus is more likely to be the result of a specific adaptation and less likely to be a basic property of the auditory system. In contrast to their arguments about most music processing, Justus and Hutsler (2005) do not argue that there are parallels to metre in other cognitive domains, though Fabb and Halle (2006) do discuss the role of metre in English poetry, suggesting that there is a metrical grid

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2 Similar, but not identical principles appear in music from other cultures, for example, the concept of *taal* in Indian classical music; the important principle is that most forms of music have some form of regular alternation of weak and strong beats.
that underlies the way English poetry is performed. The relationship between the Fabb and Halle (2006) metrical grid and metre in Western music is yet to be determined.

Though not all music is intended to imply a metre (e.g., Gregorian chant), there is evidence that listeners from at least most musical cultures are able to construe the presence of a metre (Nettl, 2005); many cultures – for example, the Ewe people of Ghana (Pressing, 1983) – typically use much more complicated forms of metre than those typically used in Western music. There is evidence of architectural constraints on the perception of metre; cognitive neuropsychological research appears to show a dissociation between the processing of rhythm and the processing of metre, suggesting that architectural constraints on the structure of the brain have influenced the localisation of musical processing (e.g., Peretz, 1990; Schuppert, Munte, Wieringa, & Altenmuller, 2000; see Section 3.3.2.3). Hannon and Trehub (2005) showed, firstly, that North American six-month-olds were capable of detecting alterations to metrical structure, and, secondly, that North American six-month-olds were just as good at detecting complex Macedonian-Bulgarian metres as simpler Western metres. This suggests that, although infants may be predisposed to hear metrical structure, they are not predisposed to hear particular kinds of metre. Thus, there may be evidence of chronotopic constraints for the cognition of metre. In summary, although more research needs to be done in regard to the way that metre is processed, it appears that there could be a process specialised for metre that is an evolutionary adaptation.

Evolutionary explanations of temporal grouping processes and metre often focus on the social function of music (e.g., Brown, 2000; Cross, 2003; Dean, Byron, & Bailes, in press; Merker, 2000). Music in modern hunter-gatherer societies often centres on a participatory form of music in which all participants in the music contribute to the sound, and in which music and movement are thought to be two facets of the same phenomenon (e.g., Blacking, 1973). Cross (2003) argues that, in hunter-gatherer societies, the emotions of members of the society can be manipulated and synchronised through the use of music, thus leading to greater social cohesion and better ability to exploit the environment and compete against other groups of hunter-gatherers. Dean et al., in press, argue that the perception and production of metre and temporal information has become an adaptation through the mechanism of sexual selection, as it facilitates dance, which Dean et al. argue is a direct indicator of bodily
symmetry; bodily symmetry has often been considered an important aspect of evolutionary fitness.

In summary, there are plausible evolutionary mechanisms for explaining how the perception of metre and temporal grouping came about, and it appears plausible that there are architectural and chronotopic constraints that influence the development of metre. Thus, it is plausible that the implicit construction of metre is an adaptation. However, although there have been some attempts at cross-cultural research in the area (e.g., Hannon & Trehub, 2005), more research is needed on how metrical structure works in other cultures, especially as it is generally recognised that metre is among a variety of forms of durational information that are typically less complex in most Western styles of music than in music from many non-Western cultures (e.g., Pressing, 1983).

### 2.4.3 Melodic Contour and Relational Memory For Melodies

As explored in more detail in Appendix A, melodic contour appears to be an important feature of music for most cultures. Justus and Hutsler (2005) suggest that the cognition of melodic contour could be a candidate constraint. Similarly, McDermott and Hauser (2005) focus on the possibility that relational pitch processing could be an adaptation; it is argued at length in Chapter 3 that the cognition of melodic contour, as measured in empirical research, should more accurately be referred to as relational memory for melodies, as the empirical research that found that melodic contour was salient did so in a context where the relevant form of memory was for the relationship between pitches in melodies.

Relational pitch memory appears early in infant development, as a sample of North American infants orientating to stimuli appear to treat two identical but transposed melodies in different keys as the same (Trehub, Thorpe, & Morrongiello, 1987). This suggests that there may be chronotopic constraints on infant development of relational memory for melodies; supporting this claim, adult musicians who have absolute pitch have significantly more difficulty discriminating between melodic contour alterations
to melodies in different keys than adult musicians without absolute pitch (Miyazaki, 2004). Neuropsychological evidence suggests that the right superior temporal gyrus is involved in relational memory for melodies (e.g., Peretz, 1990; see Section 3.3.2), suggesting a possible architectural constraint. Thus, it is plausible that there are chronotopic constraints and architectural constraints to relational memory for melodies, and it is thus plausible from the perspective of Justus and Hutsler (2005) that relational memory for melodies is the result of an evolved neural mechanism.

However, there is an argument that relational memory for melodies may not be domain-specific or necessarily domain-specialised to music. A variety of research indicates a similarity between the processing of melodic contour in music and the processing of prosodic contour in language. Neuropsychological patients with deficits in music processing in an experiment by Patel, Peretz, Tramo, & Labreque (1998) were poor at distinguishing differences in pitch frequency in both melodies and sentence prosodies (see Section 3.3.3). Similarly, Event Related Potential data show similar profiles for participants’ responses to processing melodic contour and their responses to processing prosodic contour, in both musicians and nonmusicians (Besson, Magne, & Schön, 2003). This suggests that the cognition of melodic contour and the cognition of prosodic contour may at least function similarly. Although more research, and especially cognitive psychology research, on this subject is needed, considering arguments that neuroscientific techniques are most useful when testing theories derived from cognitive psychology (Bergeron, 2007; see Section 3.3.1.1), evidence from Patel et al. (1998) and Besson et al. (2003) suggests that relational pitch memory may be used in either music or language – that is, more than one domain. Additionally, it has been suggested that relational memory for melodies may simply be a function of verbal working memory (Ockelford, 2007; Patel et al., 1998; Schendel & Palmer, 2007; see Chapter 4), in which case relational memory for melodies is simply the result of what are usually considered more domain-general mechanisms (though see Chapter 4, in which arguments that verbal working memory is specifically designed for language are discussed).

There are plausible arguments why the cognition of melodic contour, or relational memory for melodies, may be the result of an adaptation; specifically, the theory that the cognition of melodic contour is necessary to the singing of lullabies by mothers to
infants. A lullaby is defined by Trehub, Unyk, & Trainor as a “soothing refrain used to please or pacify infants….sung by mothers and nurses the world over to coax their babies to sleep” (1993, p. 193); lullabies appear to be common to all cultures, and adults from Western cultures could recognise lullabies from disparate cultures as being lullabies, despite the often drastic differences between musics from different cultures (Trehub et al., 1993). The central musical characteristics of lullabies are slow tempo, higher than usual pitch, and a statistically unusual amount of descending contours; this corresponds to the descending contours of infant-directed speech (Trehub et al., 1993). The lullaby hypothesis offers a plausible explanation of why there might be a link between the cognition of prosodic contour and the cognition of melodic contour. Adults talking to babies invariably use a special form of speech that exaggerates fundamental frequency, intonational contours, high levels of affect, and hyperarticulation of vowels (e.g., Burnham, Kitamura, & Volmer-Conna, 2002). Dissanayake (2000) argues that infant-directed speech is more musical than linguistic in focus. Dissanayake (2000) argues that lullabies are crucial to the early development of socialization and emotions in infants, as it enables parents to communicate and emotionally interact with altricial infants.

2.4.3.1 Further research on relational memory for melodies is necessary

Relational memory for melodies appears to involve architectural and chronotopic constraints, there are plausible arguments why it may be an adaptation, and it appears to be cross-culturally important. Though it may not be domain-specific, it therefore is a reasonable candidate for a music-related cognitive process that may be an adaptation of some sort. It is the contention of this thesis, however, that it is necessary to analyse the research that led to the argument that relational memory for melodies may be an adaptation; if the research on the cognition of melodic contour can be explained by the theory that the cognition of melodic contour is an example of relational memory for melodies, it has important implications. The first implication is that it may not be specifically the cognition of melodic contour but instead the broader category of memory for relationships between pitches that is the adaptation; this possibility is discussed in detail in Chapter 3. The second implication is that memory for relational
pitch may simply be a function of verbal working memory, and thus is not domain-specific; this second possibility is discussed in detail in Chapter 4. However, it is contended in this thesis that more empirical research is needed to investigate the assumption that the cognition of melodic contour is an adaptation. Specifically, it will be argued that there is little evidence about the role of features of music other than melodic contour in relational memory for melodies (e.g., durational information and PIM information; see Sections 3.2.2.3 and 3.2.4), and that the role of melodic contour in relational memory for melodies cannot be understood outside of that context.

Thus, more research on relational memory for melodies outside of research on melodic contour is necessary to determine the extent and nature of relational memory for melodies. Such research would improve knowledge regardless of the theory of the evolutionary emergence of music used. Firstly, under the theory of Justus and Hutsler (2005), if it can be determined that relational memory for melodies is simply a function of verbal working memory, or if future research finds a neural relationship between other parts of relational memory for melodies and the cognition of other aspects of prosody, the likelihood of relational memory for melodies as a more domain-specific adaptation becomes weaker; it becomes more likely that it is the result of more domain-general processes. Secondly, improving our knowledge of relational memory for melodies will improve our ability to make inferences about the adaptive pressures that caused that mechanism to develop, and thus lead to further knowledge about music cognition, on the grounds given by Cosmides and Tooby (1997). Finally, improving our knowledge of relational memory for melodies in humans will improve our ability to determine whether similar abilities in animals such as Rhesus monkeys (Wright et al., 2000) are homologous or analogous, thus improving our ability to determine whether such a cognitive process is the result of a neural mechanism that is an adaptation under the theory of Hauser, Fitch, and colleagues (Hauser et al., 2002).

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3 Homologous features are similar features in two species which are thought to have evolved before the evolutionary history of those species diverged (e.g., cormorants and ibises can both fly, and their most recent common ancestor could fly)
4 Analogous features are similar features in two species which are thought to have evolved after the evolutionary history of those species diverged (e.g., cormorants and vampire bats can both fly, but their most recent common ancestor could not fly)
The most convincing explanation, at present, of why relational memory for melodies might have evolved is the lullaby hypothesis, which is that infants are good at processing relational melody information because it was advantageous for infants to communicate emotionally with his or her mother and to be able to be put to sleep by the use of music. If this were the case, one should expect that other aspects of music that are processed by relational memory for melodies to also be aspects of music that would be useful in mother-infant communication; thus, if relational memory for melodies processes rhythmic information, it will process rhythmic information in such a way that is advantageous for mother-infant communication.

2.5 Conclusions

The existence of music is, at some level, the result of human evolution, but it is unclear whether music is a specific adaptation caused by natural selection or whether music is a by-product of general processes. Part of the lack of clarity regarding the evolutionary status of music is due to the existence of different theories of the evolutionary emergence of music (e.g., Justus and Hutslcr, 2005; McDermott & Hauser, 2005), that posit different criteria for determining whether something is an adaptation. A second part of the lack of clarity is due to the limitations in knowledge about evolutionary history and brain processes, and a third part of this lack of clarity is due to lack of research. However, given these caveats, it appears that it is plausible that the cognitive processing of scale categories, metre, and melodic contour are the results of an adaptation. Chapter 3 will further examine the cognitive research on memory for melodies, arguing that the cognitive processing of scale categories, metre and melodic contour are the result of one particular memory system. Chapter 4 examines the possibility that memory for melodies is a function of working memory. Chapter 5 posits a cognitive model of memory for melodies, based on the research outlined in Chapters 3 and 4. Chapters 6 to 11 will report experiments that test hypotheses made by this cognitive model of memory for melodies. If the hypotheses deduced from the model in Chapter 5 are correct, it will provide evidence that scale categories, metre, and melodic contour are all processed by an integrated memory system. In the long term, this will provide further evidence about the likelihood that relational memory for melodies has evolved.
CHAPTER 3

Relational Memory for Melodies
3.1 The Cognition of Melodic Contour is Part of Memory for Melodies

Considering that the cognition of melodic contour is one of the aspects of the cognition of music most likely to be an evolved neural mechanism (see chapter 2), it is necessary to review the literature on the cognition of melodic contour. This chapter will argue that the cognition of melodic contour is not a unitary self-contained mechanism, but instead is a component of relational memory for melodies, along with the cognitive processing of other musical attributes such as scale and interval. Thus, this chapter will review the developmental, cognitive, neuropsychological, and neuroimaging research that has involved short term memory for melodies, and will consider the cognition of interval size, tonality and duration in addition to melodic contour. This chapter will demonstrate that the cognition of melodic contour cannot be considered separately from the cognition of other musical features. Secondly, this chapter will show that the relationship between the cognition of melodic contour and the cognition of pitch interval size is surprisingly unclear, and that it may be more useful to conceive of the processing of melodic contour as a form of pitch accent structure (M. R. Jones, 1993). Thirdly, this chapter will demonstrate that memory for melodies cannot be considered without reference to durational information. Finally, this chapter will show that there is little neuropsychological or neuroimaging research that indicates that there are separate neural resources for the processing of melodic contour and the processing of pitch intervals.

3.2 Memory for Melodies is Relational, Abstract, and Different from Pitch Memory

Researchers have attempted to identify the melodic features that are used in adult memory for melodies, and to identify variations in the way these features are used with different task constraints. Memory for melodies is a memory for the relationships between pitches and therefore involves either abstraction or the recognition of higher-order configurations (J. Davies, 1979; see Appendix A for further information on this definition) Dowling’s (1978) term memory for melodies typically refers to
short term memory for melodies, and in this thesis the term memory for melodies will refer to short term memory for melodies, except where specifically indicated. Some research in the area of memory for melodies has used interstimulus intervals (ISIs) of 30 seconds or 15 minutes (e.g., Dowling & Bartlett, 1981); these lengths of time are usually considered to involve LTM. However, most research involves STM paradigms. Studies using longer ISIs largely avoid using intervals longer than a few minutes, and they are usually framed as an extension of STM research rather than an attempt to examine LTM (e.g., Dowling & Bartlett, 1981). Broadly, themes that emerge from this literature include the importance of features of melodies such as melodic contour, interval size, tonality, rhythmic pattern, and hierarchical grouping processes. Secondly, the relative importance of these features changes depending on the musical training of subjects completing the task, the length of the melody, the familiarity of the melody for the participant, and the time interval between hearing a melody and making a judgment about its relationship to other melodies.

Adult memory for melodies should not be confused with pitch memory; however, adult memory for memories may use information from pitch memory. A series of experiments by Deutsch (1975) explored human memory for individual pitches. In Deutsch’s paradigm, a same-different task (e.g., Deutsch, 1972), participants would hear a standard pitch followed by some form of distraction (e.g., spoken numbers or tones). Participants would have to determine whether a comparison pitch was different to the standard pitch. Deutsch (1975) argued, based on the results of research largely using this paradigm, that pitch memory is separate from memory for linguistic information, as distractor tones interfere more with pitch memory than distractor speech.

However, it is clear that memory for melodies is separate to memory for individual pitches (J. Davies, 1979; Deutsch, 1975; Dowling, 1982), as participants can discriminate changes to melodies despite absolute pitch information being absent. For example, Dowling and Fujitani (1971) used a same-different task, and manipulated whether the melodies were transposed in key – one melody was in the key of C major, whereas the other melody was in a random key that, although it used different pitches, used the same pitch interval ratios between the pitches. For example, the pitch sequence E4 D4 C4 has the same pitch intervals as the pitch sequence Bb4 Ab4 Gb4.
As both sequences involve two falling intervals of two semitones, they are sonically equivalent; played isochronously, either could be recognised as the start of the nursery rhyme ‘Three Blind Mice’. Dowling and Fujitani (1971) found that, although participants were significantly better at detecting alterations to melodies in untransposed melodies, they were still able to tell the difference between melodies based on the melodic contour in transposed melodies. As transposing a melody means that the melody either uses completely different pitches, or uses some similar pitches in different serial positions, participants cannot use pitch memory to tell the difference between the melodies. Thus, listeners must rely on information about the relative pitch intervals between notes in order to successfully discriminate transposed melodies. Additionally, Attneave and Olson (1971) found that participants without musical training were more accurate at transposing familiar melodies than at transposing isolated intervals (e.g., an interval of 7 semitones). These results provide evidence for the assertion by J. Davies (1979) that memory for melodies is a substantially different entity to pitch memory. The former is essentially relational in focus and resembling working memory in nature, whereas the latter appears to be the result of a specialised immediate memory system for pitch (Deutsch, 1975).

Infants are capable of the relational processing of melodies, suggesting that memory for melodies occurs early in development. Trehub (2003) argues that relational information predominates melodic processing in infancy. Support for this comes from Chang and Trehub (1977a), who measured the heart-rate of 4.5 to 6 month olds who were habituated to a standard atonal melody for 15 trials, and were then presented with a different melody, that either transposed the standard melody, or scrambled the note order in the standard melody. Though the same pitches were used in the scrambled version, babies dishabituated with an increased heartbeat to the scrambled melodies, but did not dishabituate to the transposed melody. This lack of dishabituation supports the argument of Chang and Trehub (1977a) that infants are capable of relationally processing melodies.

### 3.2.1 Memory for Melodic Contour

This section will review the cognitive psychology literature on memory for melodic contour. It will show that most research on melodic contour has involved tasks using
memory for melodies, and will discuss the advantages and limitations of the most commonly used task, the melody discrimination task. Firstly, this section will show that melodic contour is salient to infants, adults who have been enculturated into the Western musical tradition, and adults with extensive musical training. Secondly, this section will show that memory for melodic contour is additionally not specific to melody discrimination tasks, and its salience has been shown in a variety of experimental tasks. However, this section will demonstrate that melodic contour is more salient when situations encourage the use of STM knowledge, and less salient when tasks and stimuli encourage the use of LTM knowledge.

3.2.1.1 Memory for melodic contour in infancy

The ability to differentiate between melodies based on melodic contour is present in infancy; that infants have this ability may suggest that it does not require extensive long term memory knowledge about music. However, no widely available published infant research which has tested the salience of melodic contour alterations to infants has used transposed comparison stimuli, which makes ascribing this discriminability to the role of memory for melodies problematic. In any case, whether memory for melodies is involved, the exaggerated contours of both lullabies and infant directed speech are salient to infants (e.g., Fernald & Mazzie, 1991; Trehub, Unyk, & Trainor, 1993). Trehub and colleagues (Trehub, Bull, & Thorpe, 1984; Trehub et al., 1987) used a visually reinforced head-turn procedure, in which infants turn their head for a longer period of time to a loudspeaker emitting unexpected melodies for a longer than to a loudspeaker emitting expected melodies. Trehub et al. (1984) tested the ability of 8-11 month olds to discriminate transpositions, interval alterations, and contour alterations in six note tonal melodies. Trehub et al. found that infants were able to discriminate melodies with these alterations, though they were significantly better at discriminating contour alterations compared to interval alterations or transpositions. However, when a distractor melody was played between the standard and different melodies, infants could discriminate contour alterations but could not discriminate transpositions or interval alterations. That contour alterations were more salient than transpositions either suggests that infants are using pitch memory rather than memory for melodies to complete the task, or that infants treat transposed melodies as the
same as the original melody (also see Chang & Trehub, 1977a). Trehub et al. (1987) used a similar paradigm in testing 8-11 month infants. There were two conditions; a control condition where infants turned their heads to alterations to interval size (half of which had alterations to four intervals, half of which had alterations to two intervals, none of which had alterations to contour) or transpositions, and an experimental condition, that used the stimuli from the control condition as standard stimuli and compared them to melodies with contour alterations. They found that infants discriminated alterations to the melodic contour more often than they discriminated alterations in the control condition (46% versus 21%). Unfortunately, comparison melodies with melodic contour alterations were untransposed, and Trehub et al. (1987) collapsed infant responses to transpositions and infant responses to interval alterations into one condition, which makes interpreting their results difficult from a memory for melodies perspective. However, whether or not pitch memory or memory for melodies is involved, it is clear that infants can discriminate alterations to melodic contour, which suggests that it does not require extensive long term knowledge.

### 3.2.1.2 Melodic contour is salient to memory for melodies in short, unfamiliar melodies at short intervals

Melodic contour is not only salient for infants, but has been shown to be a particularly salient feature of melodies for both adult musicians and nonmusicians in a variety of tasks and contexts. The most widely cited experiment involving memory for melodic contour is that of Dowling (1978), who used a melody discrimination paradigm; participants with and without musical training hear one melody, followed by a short pause, and a second melody. As standard stimuli, Dowling used novel tonal melodies that were monophonic, isochronous and five notes in length, and that were constructed so that step intervals were twice as likely as leap intervals. In all melody pairs, melodies were transposed from the key of C in the standard stimuli to the key of A or the key of E in the comparison stimuli. There were three conditions with different comparison stimuli. In the first condition, the comparison stimuli were tonal answer melodies; these melodies had one note alteration that deliberately changed the tonality of the melody but did not change the melodic contour. In the second
condition, the comparison stimuli were atonal melodies; these melodies had note alterations so that no consistent tonality could be determined from the melody, and these melodies had no alterations to melodic contour. In the third condition, there were random tonal melodies with different melodic contours. Dowling found that both the musically trained and untrained subjects performed at chance in discriminating the tonal answer melodies, suggesting that alterations to intervals were not salient in transposed 5-note tonal melodies. In contrast, the difference between the standard melody and random melodies was salient for both musicians and nonmusicians; the difference between the standard melody and the atonal melody was discriminable for both musicians and nonmusicians, but was significantly more discriminable for the musicians.

Dowling used these results to argue that the two main components of adult memory for melodies were melodic contour and tonality. Dowling (1978, 1982) argued that participants in his experiments are not using accurate note-to-note pitch interval information, but instead are relying on the basic contour of the melody, supplemented by knowledge of the tonal scale used in the melody, which aids in the chunking and processing of the melody (the role of tonal scale information in adults is discussed in Section 3.2.3.3 of this chapter). However, Dowling’s (1978) experiment does not merit his conclusions about the importance of melodic contour compared to interval information. Firstly, as later experiments showed (see below), melodic contour is only more salient than pitch interval information in melodies that are short, unfamiliar, and have been heard recently. Secondly, the interval alterations made in the tonal answer condition were deliberately conflated with information about the key of the melody. Thirdly, though Dowling (1978) did not publish the full stimuli used in his experiment, in the examples published there is one note alteration in the tonal answer condition, two note alterations in the atonal condition, and 4 note alterations in the random condition. Dowling (1978) found that contour alterations (i.e., the random condition) were more salient than the removal of tonality (i.e., the atonal condition), which were more salient than the alteration of tonality (i.e., the tonal answer condition). These results are consistent with the hypothesis that it is the amount of changed notes, rather than the kind of alteration, that is salient to participants.
However, although this experiment is problematic for the aforementioned reasons, it does appear that experiments using variations of the paradigm used by Dowling, involving adult participants with or without musical training, have consistently shown that melodic contour is salient to memory for melodies. Experiments using essentially similar same-different paradigms to Dowling (1978), with novel monophonic isochronous melodies transposed between standard and comparison melodies, include several other experiments by Dowling and colleagues (Bartlett & Dowling, 1980, Experiment 1; Dowling, 1991; Dowling & Fujitani, 1971), a series of experiments by Edworthy (1983, 1985a, 1985b), and experiments by Dewitt and Crowder (1986), Dyson and Watkins (1984), and Mikumo (1992, 1997). All of these studies have found that melodic contour is salient to some extent in adult memory for melodies. However, these further experiments do suggest that melodic contour is most salient with short ISIs, with short, unfamiliar melodies.

3.2.1.3 Melodic contour is less likely to be salient to memory for melodies in long or familiar Melodies, or at longer intervals

The discrimination of melodic contour is less likely to be accurate in melodies that are more familiar, longer, or were heard more than a few seconds ago. The salience of contour decreases as the length of the melody increases. Edworthy (1985a) found that the salience of contour to participants with musical training, measured in reaction time to the changed note, decreased as melody length increased (in melodies with either 3, 5, 7, 9, 11, 13, or 15 notes). Further evidence for this argument is found in earlier experiments by Edworthy (1983; 1985b), using a similar paradigm to Edworthy (1985a), except that 5 note melodies were contrasted with 15 note melodies. Edworthy (1985a) found that contour alterations were less salient in 15 note melodies than 5 note melodies, using accuracy measures. Additionally, Dyson & Watkins (1984) manipulated the tempo of 15 note melodies in Experiment 1 so that melodies were presented at either 240 beats per minute (BPM), 171 BPM, or 600 BPM. They found that participants were more accurate at detecting both alterations to contour and to interval at slower tempos, suggesting that, at the tempi used in their experiment, interference may be stronger than decay in memory for melodies.
The salience of contour decreases as the ISI increases. Dowling and Bartlett (1981) demonstrated, in a series of experiments, some using naturalistic stimuli (extracts of Beethoven string quartets) and some using artificial melodies, that the importance of contour decreases in long term memory situations. In a task with similar melody alterations to those of Dowling (1978), participants were less likely to regard comparison melodies with same contour but different intervals as the same as the standard melodies when there were delays of 5 mins than when there were delays of 5 s. Dewitt and Crowder (1986) found that, with seven-note tonal melodies, alterations to contour were more salient to (presumably musically untrained) participants after an ISI of 1 s than after an ISI of 25 s. Additionally, Dowling (1991), using isochronous transposed seven note melodies, replicated the results of Dewitt and Crowder (1986) with tonal melodies. However, in atonal melodies, Dowling found no decrease in the salience of contour alterations to either musically trained and untrained participants after long ISIs (on average, 39 s) compared to short ISIs, which suggests that the decline in the salience of melodic contour in long term memory is specifically related to the representation of tonality in long term memory.

Finally, the salience of contour, relative to the salience of interval size, declines as the familiarity of the melody increases. Dyson and Watkins (1984) reported that alterations to contour were less salient in comparison with alterations to exact interval size after a familiarization procedure, in which participants were played the melodies before the experiment. Other researchers have noted that alterations in interval size are more salient in familiar melodies relative to the salience of melodic contour (e.g., Dowling & Fujitani, 1971; Bartlett & Dowling, 1980). Additionally, studies of memory for melodies with 5-6 year old children as participants (e.g., Dowling & Bartlett, 1980; Trehub, Morrongiello, & Thorpe, 1985) have, by necessity, used familiar melodies such as “Twinkle Twinkle Little Star”, as pilot testing indicated a floor effect in regard to the discrimination of unfamiliar melodies in 5-6 year olds. These results suggest that the melodic contour becomes less salient as the familiarity of the melody increases.

In summary, it appears that, when tested using discrimination tasks, melodic contour is more salient in shorter melodies, more salient in more familiar melodies, more salient in atonal than tonal melodies, and more salient with shorter ISIs. These results
strongly suggest that the cognition of melodic contour is related in some way to short
term memory processes, and that long term memory for melodies is substantially less
reliant on melodic contour.

3.2.1.4 Issues in the use of melody discrimination tasks to
determine whether musical features are processed by
memory for melodies

Using the melody discrimination task to investigate memory for melodies is not
without problems. Firstly, it is possible that the discrimination task paradigm
overestimates the level to which participants have knowledge of the melody. J. Davies
has argued (J. Davies, 1979; J. Davies & Jennings, 1977) that a melody is not solely a
list of notes but instead an integrated whole, which leads to the possibility that
participants recognise the melody based on severely degraded memory traces.
However, statistical procedures like the Memory Operating Characteristic (Swets,
1973), most notably used in the series of experiments by Dowling, or Hit minus False
Alarm rates (HR-FA), which incorporate information about the participant’s certainty
of response, ameliorate this problem to the extent that, if stimuli are degraded to the
extent that participants are guessing, the HR-FA calculation will take this into
account.

There are also stronger criticisms of the melody discrimination task, related to its
ecological validity. Firstly, it is problematic to solely use recognition tasks in the
testing of memory for melodies, as the cognitive processing related to the demands of
the task may be mistaken with the cognitive processing related to the everyday use of
music, especially as most tasks use simple, short, isochronous melodies, compared to,
for example, pop songs, which are usually significant longer than 5 notes long, and
neither isochronous nor monophonic. Researchers have therefore endeavoured to test
these assumptions using other paradigms (see Section 3.2.1.5).

Secondly, like many other tasks used in cognitive psychology, melody discrimination
tasks are not ecologically valid for most participants, except perhaps aurally trained
listeners such as musicologists or musicians. It is unlikely that most Western listeners
are regularly consciously analysing melodies for similarities and differences in the
melodic contour. Instead, as L. Meyer (1956) and Huron (2006) make clear, most Western listeners are listening to music for aesthetic reasons. Whether the music is listened to as background music, considered as art, or danced to, it is clear that the conscious comparison of similar melodies is not usually a significant part of this aesthetic experience. However, as Dowling (1978) points out, although the conscious analysis of the differences between melodies is not part of everyday listening, it is likely that the unconscious or implicit analysis of musical attributes such as melodic contour are necessary to the comprehension of the music. As such, accomplished musicians and composers should be expected to systematically use musical attributes such as melodic contour as compositional devices. For example, Dowling & Bartlett (1981) argue that Beethoven systematically used alterations to melodic contour as a musical device. Tagg (2003) argues that melodic contour is an important musical feature in pop music. Similarly, the ethnomusicological literature (e.g., Adams, 1976; see Appendix A for a more detailed analysis) suggests that the systematic use of melodic contours as a musical device is widespread, and the Indian concept of the rag is an improvisational form that specifies the use of a certain scale, and additionally specifies certain melodic patterns (Dowling, 1982). As melodic contour appears to be widely used as a compositional device, the assumption that memory for melodic contour is necessary to musical comprehension is in many cases valid.

Especially if memory for melodic contour is necessary for musical comprehension, but conscious comparisons of melodic contours are rarer, it may be that the explicit processing of melodic contour, as measured using paradigms such as the melody discrimination task, may differ from its implicit processing. Although Dowling (1982) was initially uninterested in whether the processing is implicit or explicit, Mikumo (1992, 1997) finds evidence that encouraging participants to use explicit memorisation techniques such as visualization have a beneficial effect on melody discrimination; conversely these results also suggest that these memory techniques are not required for melody discrimination. Given recent evidence that implicit memory for music, as measured by priming tasks, can operate in apparently different ways to explicit memory for music, as measured by recognition tasks (Tillmann, Bharucha, & Bigand, 2000), it may be that separate memory processes may be involved. The issue of explicit memory compared to implicit memory, however, is beyond the scope of the experimental program detailed in this thesis (see Chapters 6 to 10).
3.2.1.5 Melodic contour is salient to memory for melodies when tested using tasks other than discrimination tasks

There are several experimental psychology studies that use alternative tasks to the standard melody discrimination paradigm (Arom & Furniss, 1993; J. Davies & Jennings, 1977; Dowling & Bartlett, 1981; Dowling, Tillmann, & Ayers, 2002; Gerardi & Gerken, 1995; Lamont & Dibben, 2001; Stevens & Latimer, 1992). Such melody discrimination tasks have been criticised as *metamusical* tasks that do not use real, ecologically valid, music and situations; as such our ability to build a picture of memory for music based solely on these tasks is limited (Ockelford, 2007). However, studies using alternative tasks further show that melodic contour is salient in memory for melodies. Gerardi and Gerken (1995) found that adult listeners rated melodies that had mostly ascending contours as having more positive affect than melodies that had mostly descending contours whether those melodies were in major or minor tonalities. This suggests that melodic contour can lead to affective response. To analyse the dimensions upon which musical similarity is based, Lamont and Dibben (2001) used factor analysis of listener ratings of similarity between extracts from piano pieces written by the composers Beethoven and Schoenberg. The results suggested that similarities in melodic contour were salient to both musicians and nonmusicians in tonal music, but were substantially more salient for both musicians and nonmusicians in atonal music. Lamont and Dibben (2001) argue that similarity ratings of piano pieces in the Western art music vein are less based on deep motivic features, and more based on surface features of the music such as melodic contour. A similar analysis of musical extracts by Rosner and L. Meyer (1986) for participants’ ratings of similarity similarly found that melodic contour was an important aspect of the similarity ratings assigned by participants (Rosner & L. Meyer give no information about the musical training of their participants). It should be pointed out that both Lamont and Dibben (2001) and Gerardi and Gerken (1995) differentiated melodic contour on the basis of general melody direction (i.e., up versus down), as opposed to the focus on changes in direction in melody discrimination tasks. These experiments show that melodic contour is salient in situations not involving the melody discrimination task.
A production task by J. Davies and Jennings (1977) asked musically trained and participants without musical training to visually reproduce melodies. Firstly, they had to draw the shape of the familiar melodies on pieces of paper as they listened to them, and J. Davies and Jennings compared the pitch direction of the actual melody with the direction of the drawing. Secondly, there was a magnitude estimation task, where participants wrote an estimate, in numbers, of the differences in interval magnitude in the melodies. Davies and Jennings found that participants with musical training were more accurate at drawing contour than participants without musical training, and that all participants were more accurate at drawing contours than estimating the size of intervals. There are some problems with this method, however, in that it is unclear that the contour task and the interval magnitude task were equivalent in difficulty, as they required different forms of responses. However, the task does show that both musicians and nonmusicians are reasonably accurate in their producing contour drawings of familiar melodies, further suggesting that the importance of melodic contour to memory for melodies is not simply a result of artificial melodies and task requirements.

Stevens and Latimer (1992) used a contour categorization task in Experiment 2. In this task, participants had to distinguish between four-bar-long tonal melodies on the basis of whether melodies had smooth or jagged contours, where a smooth contour was composed mainly of pitch intervals of three or less semitones, and a jagged contour was composed mainly of pitch intervals of four or more semitones. Participants were not told that they were distinguishing melodies as jagged or smooth, however, but instead were to place melodies into two categories on whatever basis seemed appropriate. Both musicians and nonmusicians correctly categorised melodies at levels of above chance. This suggests that participants are not only sensitive to alterations to melodic contour, but also sensitive to global features of contour shape that do not involve contour direction.

Finally, Dowling et al. (2002) used a novel variation on the melody discrimination task; instead of a standard melody discrimination task where two discrete melodies were compared to each other, the experiments they reported use a comparable but much more ecological valid task, wherein the stimuli were drawn from dance music (e.g., minuets and waltzes) from the classical period. In their experiments, participants
listened to an extract from these pieces where participants were asked to indicate whether a target phrase from the beginning of the melody was exactly the same, similar, or different to a phrase which was, for example, 30 s into the piece. Similar phrases shared the melodic contour of the target but had different intervals, different harmonic and rhythmic accompaniment or different timbres, or some combination of the above. Though the time periods between the target and the test phases were unusually long, participants were quite accurate at the task when there was coherent musical information between the target and the test phase, and were less accurate when there was silence or scrambled musical information; Dowling took this unusual accuracy after long periods to suggest that the presence of coherent musical structure leads to a highly accurate and specific cognitive structuring of time which greatly aids memory.

3.2.1.6 Conclusions regarding the role of melodic contour in memory for melodies

Research using different paradigms, including melody discrimination tasks (e.g., Dowling, 1978), similarity judgements (Lamont & Dibben, 2001), recall tasks (J. Davies & Jennings, 1977), and judgements of affect (Gerardi & Gerken, 1995), strongly suggests that melodic contour is important to memory for melodies, and, more generally, the cognition of music. Additionally, research consistently shows that the recognition of melodies based on melodic contour is strongest when the situation encourages short term forms of retention – that is, with shorter melodies and ISIs, and with less familiar melodies. It should be noted, however, that there is little research on the role of LTM in the cognition of melodic contour that does not use the melody discrimination task. It should be clear from this literature review that almost all research studying memory for melodic contour has found that other musical features, such as interval and tonality, are retained in memory for melodies to some extent. This supports the theoretical position stated at the start of this chapter that the cognition of melodic contour is best thought of as a component of memory for melodies. The next sections of this chapter will examine, in turn, the role of interval, scale, and rhythm in memory for melodies.
3.2.2 Memory for Intervals

Dowling (1982) argues that alterations to interval are more salient in long term situations, and thus that memory for interval is more reliant on LTM knowledge than memory for melodic contour. However, the situation is complicated. Firstly, different researchers have approached and defined interval alterations in different ways, with some studying exact interval size (EIS), and others studying pitch interval magnitude (PIM). Previous research has often conflated the two, or viewed them as similar kinds of alterations, but the trend in that research suggests that EIS is more reliant on LTM knowledge than PIM. Secondly, studies of EIS are problematic as alterations to EIS almost always also involve some level of alteration to tonality. Finally, infants may be capable of discriminating between melodies on the basis of alterations to exact interval size, which goes against the LTM hypothesis.

EIS is considered to be part of the local shape of a melody, where melodic contour is considered part of the global shape of a melody (Dowling, 1978). However, as the alteration of one note by a semitone, the smallest possible alteration using Western tonality, can change tonality significantly, Dowling clearly considers alterations to EIS to be, effectively, alterations to tonality. In his 1978 experiment, where melodies in C major were transposed to melodies in A major or E major, the tonal answer condition changed a major third in those melodies to minor third, effectively keeping the same tonality as the melody in C major. This was done deliberately to test the role of tonality. In contrast, PIM, which divides pitch intervals into steps (intervals that move one note up or down the scale being used in a melody, which usually is equivalent to a change of one or two semitones) and leaps (intervals that move more than one note up or down the scale being used in a melody, which is usually equivalent to a change of three or more semitones), without concern for the exact interval size of steps or leaps, is more commonly considered as a part of the global shape of a melody, and is less subject to conflation with changes in tonality. M. R. Jones (1993) considers leaps to contribute to melodic accent structure, which she argues is the main contributor to the perceived global shape of the melody, whereas Stevens and Latimer (1992) argued that PIM is a basic building block of global shape, and differentiated between smooth contours, with mostly steps, and jagged contours, with mostly leaps. Peretz (1990) and Edworthy (1985a) also consider EIS to be a local
aspect of a melody; however, in the interval alterations used in their experiments there are often quite large changes in interval size – e.g., four semitones – that could be argued to be a change to PIM, and thus not necessary a local aspect of a melody.

3.2.2.1 Memory for interval size is present in infancy

Mixed evidence about infants’ ability to discriminate alterations to interval size is problematic for the hypothesis that memory for intervals is highly reliant on LTM information. Dowling (1982) argued that infants are insensitive to alterations to interval size and tonality. 18-month-olds are insensitive to interval size and tonality, based on observations of their spontaneous song. In comparison, the spontaneous song of 32-month-olds is still insensitive to tonality but more sensitive to phrase structure and interval size; Dowling suggests that “the child has moved from Frank Zappa somewhat in the direction of the Beatles” (1982, p.417). However, results appear to suggest that, although infants have problems producing phrase structure and interval size, they are capable of the cognition of interval size. The results of Trehub et al. (1987) suggest that infants can discriminate between melodies on the basis of interval size, despite that they argue that their results suggest that melodic contour is salient and interval size is not. In a control condition, infants were able to discriminate between melodies on the basis of transposition or interval size change. In the experimental condition, infants were additionally reinforced with the illumination of a mechanical toy when they correctly picked a contour alteration, but were not reinforced when they correctly picked an interval size alteration; infants were, unsurprisingly, twice as likely to pick contour alterations than interval size alterations/transpositions under these conditions, but interval size alterations/transpositions were still somewhat salient according to their results, even when not reinforced. It would be informative to see what results would be obtained with the reinforcement of responses to interval size change melodies. Thus, the assertion of Trehub et al. (1987) that infants encode contour information but not interval information is not supported by their results. Additionally, an experiment by Balaban, Anderson, and Wisniewski (1998) provides evidence that, using a head-turn paradigm, infants can discriminate between melodies on the basis of either interval size changes or contour changes. Thus, experimental evidence (Trehub et al., 1987;
Balaban et al., 1998) appears to suggest that, although infants may not yet be sensitive to interval size in their spontaneous song, infants can discriminate between melodies on the basis of interval size.

3.2.2.2 Memory for exact interval size

Research has thus far generally suggested that memory for exact interval size is not as reliant on short term retention as memory for melodic contour. In fact, counterintuitively, researchers have found increases in the salience of interval size as the contribution of long term knowledge increases. In the short term situation described in 3.2.1.2, Dowling (1978) found that exact interval size was not salient to memory for melodies. Edworthy (1985a) has argued that the salience of interval size increases over melody length; where the reaction times of participants with musical training to changes in contour decreased as melody length increased, the equivalent reaction times to changes in interval size stayed roughly the same across melody lengths, suggesting that it was not subject to the same capacity limit as melodic contour. Similarly, Dowling and Bartlett (1981) found that, although the salience of contour decreased as a result of an increase in ISI, the salience of interval increased. Dowling (1991) replicated this effect with tonal melodies, but, similarly to the aforementioned finding that the salience of contour did not decrease in atonal melodies, Dowling found that the salience of interval did not increase in atonal melodies. This may suggest that long term memory information is used in memory for interval size in a manner in which it is not used in memory for melodic contour.

3.2.2.3 Memory for pitch interval magnitude

Dowling (1978) has suggested that it would be an efficient way of encoding melodies; similarly, Kim, Chai, Garcia, & Vercoe (2000) demonstrate that the identification of melodies by computer algorithms is most efficient when the algorithms analyse both contour and PIM. However, there is a strong argument that PIM will be encoded in memory for melodies, this argument has not been systematically investigated. Furthermore, most research in the area is limited in its ability to inform us about relational memory for melodies, for methodological reasons. However, existing research suggests that it is not as reliant on LTM as exact interval size may be, but simultaneously that it is more salient in long melodies than contour appears to be.
Alterations to PIM may be most salient with short reaction times, rather than long reaction times. In an experiment by Peretz and Morais (1987), participants without musical training discriminated melodies that either had alterations to contour or PIM. Participants were assigned to two conditions; one in which they were encouraged to respond as quickly as possible, and one in which they were not given instructions. Peretz and Morais did not transpose the comparison melodies in this experiment, and do not detail whether the interval alterations altered the tonality. They found an interaction between melody change type and response condition, using mean correct responses rather than HR-FA; participants were significantly better at detecting alterations to interval when they were asked to respond quickly than when not asked to respond quickly. This may explain the difference between Dowling’s (1978) finding that the role of interval was negligible and Edworthy’s (1985a) finding that it was important to memory for melodies, especially as Edworthy’s (1985a) stimuli could be classified as having alterations to PIM; Edworthy measured reaction time, whereas in Dowling’s experiments, participants marked their responses on paper, and reaction time was not measured. However, it is unclear how much of this difference in melody salience according to response speed is due to the effects of pitch memory or the effect of tonality, as Peretz and Morais (1987) did not transpose their stimuli and do not mention whether they controlled for alterations to tonality in their stimuli.

Alterations to PIM appear to be salient to participants in transposed melodies. The participants in a control condition in a neuropsychological study by Peretz (1990), as part of a battery of tests, listened to tonal melodies that were transposed by either five or seven semitones, and that were between 8 and 19 notes long; this condition had some melodies with contour and some with interval alterations. Peretz found that participants in a control condition were significantly better at detecting alterations to contour than alterations to interval. Peretz additionally analysed control participants’ performance at discriminating between untransposed short melodies compared to untransposed long melodies, and found that participants were significantly better at discriminating short melodies. However, for this analysis, Peretz collapsed untransposed contour change and interval change melodies together, and did not include transposed melodies in the analysis. This lack of a separate analysis of contour and PIM is unfortunate as it may have provided a test of the contour as short
term memory versus interval as long term memory hypothesis (e.g., Edworthy, 1985a).

Both increases and decreases in PIM appear to be salient. In Experiment 1 by Stevens and Latimer (1992), participants with and without musical training discriminated alterations in PIM in untransposed polyphonic tonal melodies in length written in the style of a J.S. Bach chorale, that had 30 notes in the main melody part (Stevens, 1993). Stevens and Latimer found no difference in the salience of step-to-leap alterations compared to leap-to-step alterations. It is unclear what role the polyphony of the melodies used by Stevens and Latimer (1992) had on the perception of intervals in this experiment, and it should be noted that melodies were untransposed and reaction time was measured. Additionally, the comparison stimuli provided in Stevens (1993) not only had alterations to PIM but alterations to contour, which leaves open the possibility that their task was partially testing memory for melodic contour rather than memory for PIM. However, if the cognition of melodic contour is a STM process, the length of the stimuli – 30 notes long - suggests that alterations to interval rather than alterations to contour are responsible.

PIM appears to be salient in atonal melodies. In an experiment reported by Stevens and Latimer (1997), participants discriminated changes in monophonic ten-note atonal melodies. Different conditions had alterations to rhythm, alterations from a step to a leap, and alterations to both. Comparison melodies were untransposed. Both musically trained and musically untrained listeners were highly accurate in the perception of melody alterations in this experiment, to the point of a ceiling effect, suggesting that PIM is salient in atonal melodies. Compared to Dowling (1991), who argued that the increase in the salience of EIC in longer melodies was due to the effect of tonality, and should not be found in atonal melodies, this suggests that alterations in PIM may be separately processed to EIC. Alternatively, the difference between these results could be because Dowling (1991) used transposition, but Stevens and Latimer (1997) did not; thus it is possible that PIM information is retained via the use of pitch memory rather than memory for melodies.

In conclusion, it appears that memory for PIM is not extinguished in atonal melodies, PIM is salient in quite long melodies, and memory for PIM is benefited by quick
responses. This shows mixed evidence about PIM; its salience in long melodies suggests that there is some LTM component to it, but its salience in atonal melodies suggests that it is salient without LTM knowledge of tonality. However, no experiments have systematically investigated whether PIM is due to short term or long term memory, and few experiments have transposed their melodies. I intend to explore these questions in this thesis.

3.2.2.4 Conclusions regarding the role of interval size in memory for melodies

In conclusion, the role of interval size within memory for melodies has not been made clear in the literature. Where changes to interval magnitude are small, and changes are potentially confusable with changes to tonality, it appears that memory for intervals is stronger in experimental situations that use long term memory information in some way – this applies to melodies that are longer, or more tonal, or when there is a long ISI. However, where changes to interval magnitude are large, what research there is (Stevens, 1993; Stevens & Latimer, 1992, 1997) appears to show that memory for intervals is less dependent on long term memory, and is salient in situations where changes to interval magnitude do not appear to be salient. The lack of transposition in this research, in particular, and the lack of experimental conditions explicitly testing what is behind PIM mean that the role of long term memory in relational memory for interval size is still an open question and one that will be explored in greater detail later in this thesis.

3.2.3 Memory for Tonality

A series of experiments by Dowling and collaborators has shown that tonality is not only salient to memory for melodies, but that its presence or absence affects the relative salience of other musical features.

3.2.3.1 Tonality assists the chunking Of melodies
Dowling (1982) argues that listeners are better able to chunk melodies with a known tonality, as the establishment of a known tonality means listeners are able to predict which pitches are likely. It is unclear whether this increase in the efficiency of chunking occurs because the establishment of tonality serves to restrict the amount of possible pitches from 12 to 7, or because the melodic expectancies of particular note relationships in the melody (Huron, 2006) can be used to chunk melodies. Indeed, Dowling (1978) argues that tonality is one of the more salient features to memory for melodies, along with melodic contour. Following this argument, tonal melodies should be easier to remember than atonal melodies. Secondly, the more tonal the melody, the easier it should be to remember. Experiments by Dowling have confirmed both hypotheses. Firstly, Experiment 1 reported by Dowling and Fujitani (1971) used atonal melodies, whereas Dowling (1978) used tonal melodies, with largely similar paradigms otherwise. Dowling’s experiments demonstrate that memory for tonal melodies is more accurate than memory for atonal melodies. However, there was a noticeable difference in the salience of atonal comparison melodies in Dowling’s (1978) experiment between those with musical training and those without musical training; .79 versus .59, respectively (where .50 is chance). This suggests that musical training increases the salience of tonality. Indeed, this difference may be systematically underestimated by Dowling’s experiments. As J. Davies and Jennings (1977) point out, Dowling and colleagues (e.g., Dowling & Fujitani, 1971; Dowling, 1978; Dowling, 1991) have used participants from the general student population in their experiments, and classified participants as musicians if they have had over two years of formal musical training. It is difficult to tell whether the musicians in Dowling’s experiments are still active as musicians or whether their musical training occurred many years ago, and they no longer play (most likely a combination of both). Therefore it may be that Dowling’s statistic of .79 is lower than what would be expected for musicians chosen under more stringent criteria.

A later experiment by Dowling (1991) used melodies with strong tonality, weak tonality, and atonality, with contour changes and interval changes. Dowling found that the presence of tonality affected the perception of EIS and contour changes. EIS was comparatively more salient in tonal melodies, and contour was comparatively more salient in atonal melodies. If one assumes that contour information is short term and EIS information is long term in Dowling’s paradigm, then this suggests that the
presence of tonality in a melody facilitates the use of long term memory information in discriminating between melodies.

3.2.3.2 The controversy over the key distance effect

It is currently unclear whether the key-distance effect exists (Bartlett & Dowling, 1980; Croonen & Kop, 1989; Takeuchi, 1994; Takeuchi & Hulse, 1992; van Egmond & Povel, 1994). In a series of experiments using a similar paradigm to previous experiments by Dowling and colleagues (e.g., Dowling, 1978), Bartlett and Dowling (1980) manipulated the level of transposition in an attempt to ascertain more information about the role of tonality in memory for melodies. Comparison melodies were transposed to keys that were comparatively closer or further away in the circle of fifths, and the ability of participants to distinguish exact transpositions from transpositions with small changes to interval size and transpositions with changes to contour. In general, Bartlett and Dowling found that there were less false alarms to stimuli presented in keys further away from the original (C major) in the circle of fifths (e.g., the keys of E major and B major) than keys closer to the original in the circle of fifths (e.g., the keys of G major and D major), suggesting that near keys may cause more confusion about tonality than far keys.

However, the results of Croonen and Kop (1989) conflict with those of Bartlett and Dowling (1980). Croonen and Kop (1989) used seven-note melodies in C major as the standard, and melodies transposed to each possible major key, along with tonal imitations starting on each possible mode of C major. Croonen and Kop (1989) argue that their results, in which they found no influence of the similarity of the transposition key to the original key on the salience of contour changes to participants, suggest that the key-distance effect is a result of the mid-range ISI used by Dowling; they find that participants are good at rejecting tonal imitations at short ISIs (1 second), are poor at mid-range ISIs (8 seconds), but better at long ISIs (30 seconds). This suggests that there is a strong but rapidly decaying source of interval information, followed by a less accurate and slowly accumulated source of interval information. Furthermore, Takeuchi and Hulse (1992), using a similar paradigm to Croonen and Kop (1989), failed to find Dowling’s effect of key distance; in fact,
Takeuchi (1994) argues that they found a reverse key distance effect, as discrimination with near key transposition was better than discrimination with far key transposition. As such, it is unclear whether the key-distance effect exists, and unclear what contexts mediate it if it does exist.

3.2.3.3 Conclusions regarding the role of tonality in memory for melodies

Clear evidence exists that the presence of tonality has a variety of effects on memory for melodies. At a basic level, the presence of tonality leads to an improvement in memory for melodies, especially in those with musical training. Additionally, it appears to mediate the relative importance of melodic contour and exact interval size (Dowling, 1991). However, that the effect of key distance has been found by Bartlett and Dowling (1980), not found by Croonen and Kop (1989), and found in reverse by Takeuchi and Hulse (1992), suggests that further research is needed to systematically investigate factors which might contribute to the key distance effect, such as repetition, melody length, and melody complexity.

3.2.4 Durational Information in Memory for Melodies

3.2.4.1 Memory for durational information in melodies is present in infancy

If there is an inverse relationship between infants’ ability to do a task and the amount of LTM knowledge required for a task, then infants’ ability to relationally encode durational information and to use durational information in the grouping of auditory stimuli suggests that durational information does not require much LTM knowledge. Chang and Trehub (1977b) varied the location of pauses within otherwise isochronous 6-note melodies in an otherwise similar paradigm to that used by Chang and Trehub (1977a, see Section 3.2). Infants dishabituated to changes in pause location, suggesting that infants are sensitive to the location of pauses within a melody, and thus sensitive to rhythmic information. Additionally, infants integrate durational
information with grouping information. A series of experiments by Thorpe and colleagues (Thorpe & Trehub, 1989; Thorpe, Trehub, Morrongiello, & Bull, 1988) used six note melodies, where the first three notes differed from the second three notes due to changes in pitch, changes in intensity, or changes in timbre. Six-to-nine-month-olds were more sensitive to pauses inserted after two notes or four notes than after three notes. This suggests that infants, like adults, are subject to perceptual duration illusions; intervals between groups of sounds being perceptually shorter than intervals within groups of sounds. Additionally, infants do not dishabituate to habituated melodies when they are played at different tempos (Trehub & Thorpe, 1989), suggesting that infants are capable of processing duration relationally.

3.3.4.2 The relationship between dynamic pattern structure and memory for melodies

Research supports the theoretical assumption that durational information should play a large role in the functioning of memory for melodies, as durational information is the X axis to the Y axis of pitch. Much of the research regarding durational information in adult memory for melodies has been conducted by Mari Riess Jones and her collaborators (e.g., Boltz & M. R. Jones, 1986; M. R. Jones & Ralston, 1991). Jones has argued for a hypothesis specifically to do with memory for melodies called dynamic pattern structure.5 M. R. Jones (1993) argues that the most salient bits of a melody are not changes in contour, tonality, or interval magnitude, but instead the conjunction of these elements with equivalent salient bits of durational information (i.e., pauses and long notes), which Jones terms dynamic pattern structure. Boltz (1999) points out that the conjunction of these elements is important because of the large amount of accent redundancy in music. For example, an accent in a piece of music – boundaries between different sections, for example – may be simultaneously expressed by changes in volume, timbre, duration, harmony, and pitch.

As will be detailed in Sections 3.2.4.3 to 3.2.4.6, although Jones’s research does suggest that durational information is salient to memory for melodies, most of this research has not required participants to use relational information to successfully

5 Note that this is a somewhat different theory based on different tasks and materials to the Large and Jones (1999) theory of dynamic attending; see Section 8.1.2 for more information about that theory.
complete the task. No widely available published melody discrimination task involving changes to durational information appears to have transposed melodies in either key or tempo. Thus, it is currently unclear what effect the use of relational duration information will have on the function of memory for melodies.

3.2.4.3 Melody discrimination tasks involving changes in duration

Although research suggests that dynamic pattern structure is salient to memory for melodies in STM situations, this research has rarely transposed melodies in either pitch or tempo and thus may be problematic. Thus, again, effects found in this literature may be a result of absolute memory processes such as pitch memory, rather than memory for melodies. Participants without musical training in an experiment by M. R. Jones, Boltz, and Kidd (1982) discriminated unfamiliar 9-note tonal melodies on the basis of changes to EIS. The comparison melodies were not transposed in either pitch or key. M. R. Jones et al. found that discrimination was most accurate where the accents of the rhythms (e.g., relatively long notes) and the accents of the melody (e.g., changes in contour or interval magnitude) coincided. An experiment by Monahan, Kendall, and Carterette (1987) was similar to the experiment of M. R. Jones et al. (1982), except that both musically trained and untrained participants in their task judged melodic similarity rather than discriminating melodies; additionally, in the Monahan et al. experiment, melodic contour was changed rather than EIS. Monahan et al. (1987) replicated the results of M. R. Jones et al. (1982), finding that discrimination was most accurate in melodies where pitch and rhythm accents occurred together. These experiments demonstrate that both people with and without musical training are sensitive to dynamic pattern structure in melodies.

Additionally, dynamic pattern structure is salient in LTM situations. Participants with musical training in an experiment by M. R. Jones and Ralston (1991) discriminated 18-note tonal melodies within a long term memory paradigm with a 15 minute interval between stimuli familiarization and the recognition task. Untransposed decoy comparison melodies either had some pitch changes but shared dynamic pattern structure with the standard melody, or had both pitch changes and different dynamic
pattern structure. Comparison melodies were either presented in the original rhythm or a new rhythm, and participants were told to ignore the rhythm and focus on the pitch. M. R. Jones and Ralston (1991) found that, within this framework, participants were significantly more accurate at discriminating melodies where dynamic pattern structure was altered compared to melodies where dynamic pattern structure was not altered. Additionally, although told to ignore the rhythm, participants were more accurate at detecting changes to melodies when the original rhythm was present than when an altered rhythm was present. These results strongly suggest that rhythm and pitch information interact in a way predicted by M. R. Jones’s (1993) theory of dynamic pattern structure.

Further evidence that rhythm and pitch information interact in memory for melodies comes from the Stevens and Latimer (1997) experiment. In addition to testing the salience of PIM in isochronous atonal melodies (see section 3.2.2.3), they compared the ability of musically trained and untrained participants to discriminate syncopated melodies and syncopated melodies with changes to PIM. There was a ceiling effect with accuracy scores, but the reaction time data showed an interaction between rhythm and interval magnitude; participants in general responded more quickly to rhythmic changes, but were as fast with interval changes only when they occurred in the middle of the melody. Although Stevens and Latimer (1997) were not specifically testing M. R. Jones’s (1993) theory of dynamic pattern structure, the syncopation in their stimuli would presumably disrupt dynamic pattern structure in a way that would be salient. Their stimuli, in any case, show that, with comparison melodies that have not been transposed in either time or key, changes to durational information are salient.

3.2.4.4 The role of tempo in memory for melodies

Memory for melodies appears to have temporal capacity limits, in that memory for melodies decreases in accuracy as tempo increases. At a basic level, familiar melodies are recognizable when played at interonset interval (IOI) rates ranging from 150 ms to 1 s (Warren, Gardner, Brubaker, & Bashford, 1991). Boltz, Marshburn, M. R. Jones, & Johnson (1985) examined the role of tempo in the discrimination of contour
changes in isochronous 8-note tonal melodies of differing complexity by participants with musical training. Boltz et al. (1985) found that, although there was a difference in discrimination at slower presentation rates, at faster presentation rates (IOIs of 175 s), participants were more accurate at discriminating contour changes in simpler melodies. This suggests that there is a limit to the amount of information that melody for memories can process at any one time. However, Boltz et al. did not transpose comparison melodies in this task to another key or tempo, so it is possible that participants in this experiment are using pitch memory rather than memory for melodies to complete the task.

3.2.4.5 Melody recall tasks involving changes in duration

Dynamic pattern structure is salient not only in recognition but also in recall. Boltz and M. R. Jones (1986) found that, with 16- note tonal melodies, the written recall of melodies by musicians proficient in musical notation was more accurate when the rhythmic accent structure matched the melodic accent structure. Boltz (1991) similarly tested the written recall of 24-note tonal folk melodies by musicians proficient in musical notation. The original melodies were either in 3/4 or 4/4 with appropriate melodic accent structures. However, the metres of half of the stimuli were changed so that half of the melodies had joint accent structures of pitch and rhythm, and half of the melodies did not. Participants made significantly more errors in melodies that did not have joint accent structures. These results suggest that even those with high levels of musical training are prone to making more errors when the accent structure of pitch and rhythm clash, further supporting the hypothesis of dynamic pattern structure.

3.2.4.6 Conclusions regarding the role of durational information in memory for melodies

In summary, a variety of evidence using different experimental paradigms such as recognition tasks, similarity judgements and recall tasks appears to confirm the view that the presence of joint accent structure facilitates memory for the pitch or rhythmic content of melodies in both LTM and STM situations. However, considering the
relational nature of memory for melodies, it should be noted that no published melody discrimination task involving duration has yet varied the key or tempo of melodies and tested whether the effects still apply. This lack of published research is despite evidence that tempo perception affects memory for melodies (Boltz et al., 1985; Warren et al., 1991) and evidence that transposition affects memory for melodies (Croonen & Kop, 1989; Peretz, 1990; Takeuchi, 1994). Additionally, no available published research has systematically varied melody length and ISI length in a melody discrimination task using durational information as a variable. The systematic variation of ISI, melody length, and transposition would be highly informative about the way in which memory for melodies processes dynamic pattern structure. The use of transposition, in particular, will be informative as to whether the interaction of rhythm and pitch occur at a perceptual level, or at the level of abstract relational processing.

Furthermore, no available published research has specifically analysed the role of metric structure in memory for melodies. As metre is relational in nature, abstracted from the accent structure of melodies, it seems likely that metre will have a major effect on relational memory for melodies, especially given research using non-melodic click trains which shows that metre plays a large role in memory for duration (Bharucha & Pryor, 1986). However, no experiment using melody discrimination tasks has systematically varied metric structure.

Thus, further research is needed to elucidate the effects of transposition and metre on the role of durational information in memory for melodies; additionally, further research is needed to determine what role LTM has in the cognition of durational information. This thesis will investigate these questions experimentally.

3.2.5 General Conclusions About Memory for Melodies

Two main aspects of memory for melodies in which further research is needed emerge from the literature. Firstly, the boundaries between memory for melodic contour and memory for interval are unclear, in particular the boundaries between memory for melodic contour and memory for PIM. Indeed, it is possible that both
PIM and melodic contour are better thought of as part of the dynamic pattern structure of a piece of music (M. R. Jones, 1993). As no available published research into PIM has yet systematically varied melody length or used transposed melodies, it is still an open question whether memory for PIM is equivalent to memory for melodic contour. Secondly, although several studies have suggested that durational information appears to have an unsurprisingly large effect on memory for melodies, none of these studies have transposed melodies in either key or tempo, and none of these studies has examined the abstract durational property of metre; as such, it is not clear whether such studies are testing memory for melodies. Additionally, considering that there is differential use of short term and long term information in memory for melodies, no study investigating durational information in melody discrimination tasks has yet systematically varied ISIs and melody length. This thesis will further investigate the role of PIM and durational information in memory for melodies.

3.3 Memory for Melodies and Cognitive Neuropsychology

Most recent research into memory for melodies, using discrimination tasks, has been in the field of cognitive neuropsychology or neuroimaging. Indeed, one recent and influential model of music processing (Peretz & Coltheart, 2003) almost exclusively justifies itself by citing neuroimaging and neuropsychological research. Insofar as structure suggests function, memory for melodies in people who have neuropsychological deficits in the processing of music should be informative about memory for melodies in the general population. However, this section will argue that cognitive neuropsychological studies have, with some exceptions, not been especially informative about memory for melodies. That these studies have not been informative is largely due to two major limitations inherent in most of these studies. Firstly, the melody discrimination tasks used in these studies have usually not transposed melodies in key, thus making it unclear whether pitch memory or memory for melodies is responsible. Secondly, because of the limitations inherent in the analysis of those with brain lesions, stronger evidence than that presented in most cognitive neuropsychological studies of music is necessary to show that anatomical structure is
informative about the function of memory for melodies. Thus, this section will additionally argue that cognitive research will improve cognitive neuropsychological research involving memory for melodies.

### 3.3.1 Amusia

Broadly analogous to aphasia – deficits in the perception and cognition of language - amusia is usually seen as deficits in musical perception and cognition\(^6\). Most tests used by most cognitive neuropsychologists to determine the presence of amusia involve melody discrimination tasks where the ability to detect changes to intervals, tonality, contour or duration is assessed. As such, much amusia research is directly relevant to the study of memory for melodies, and can be assessed as such.

As with aphasia, amusia is not a unitary disorder, but is more an umbrella term for a variety of related disorders. Peretz and colleagues (Peretz, 1990; Peretz & Hyde, 2003) distinguish between two forms of deficits in musical ability, *acquired amusia* and *congenital amusia*. Congenital amusia is defined as “musical failures that cannot be explained by obvious sensory or brain anomalies, low intelligence nor lack of environmental stimulation to music” (Peretz & Hyde, 2003, p. 363). In contrast, acquired amusia refers to musical failures that can be explained by the presence of brain lesions caused by strokes or injuries, which can occur in the absence of problems with the recognition of environmental sounds or speech (Peretz & Hyde, 2003). Additionally, Peretz and colleagues distinguish between different forms of acquired amusia, *amelodia, arrhythmia, and atonalia*. As Peretz (1990, 1993) has defined it operationally, amelodia is, effectively, the failure to accurately discriminate between melodies on the basis of pitch (e.g., by contour or interval). Arrhythmia, in comparison, is the failure to accurately discriminate between melodies on the basis of temporal information, such as rhythm and metre. Atonalia, finally, is the failure to accurately discriminate between melodies on the basis of tonal information – a patient with brain damage as a result of an aneurysm appeared to have atonalia but not amelodia (Peretz, 1993). The differentiation of congenital amusia into subtypes is less

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\(^6\) Deficits in musical production are rarely discussed as examples of amusia, though see Peretz, Gagnon, Hebert, & Macoir (2004).
clear; Peretz and colleagues (Hyde, Zatorre, Griffiths, Lerch, & Peretz, 2006) claim that all people with congenital amusia have amelodia, whereas only half have arrhythmia.

3.3.1.1 Theoretical issues with dissociations and double dissociations

Two questions motivate much of the literature on amusia. Firstly, are domain-specific modules responsible for aspects of human cognition and perception of music? Secondly, what is the relationship of human cognition and perception of music to the human cognition and perception of language? The emphasis within this literature on neuropsychological techniques, and its general assumption of modularity within the human brain, has led to a focus on dissociations and double dissociations.

Dissociations are observed when brain damage to one neural area affects performance on task A, but not task B, where task A and task B access separate mental functions. Double dissociations are observed when, firstly, brain damage to one neural area affects performance on task A, but not task B, and, secondly, brain damage to a second neural area affects performance on task B, but not task A (Dunn & Kirsner, 2003). For example, Peretz and Coltheart (2003) argue for a double dissociation between amusia and aphasia; individuals who cannot recognise music can recognise spoken words, whereas individuals who can not recognise spoken words can recognise music.

However, the assumption that dissociations are capable of determining the presence of cognitive modules is not universally accepted. Firstly, there are empirical problems involved in determining dissociations (Stewart, von Kriegstein, Warren, & Griffiths, 2006). The location of brain lesions is usually dictated by pathological problems such as strokes, and is usually extensive, causing damage to several brain areas. In line with this, Coltheart and M. Davies (2003) point out that neuropsychological patients never have damage that only affects performance on a single task. Thus, it is difficult to precisely determine whether there are dissociations, as brain lesions are rarely confined to just one anatomical area or just one cognitive function. Secondly, the pattern of deficits after brain damage is not fixed. Because of neural plasticity,
responses on behavioural measures recorded at any significant length of time after a pathological incident may differ from responses recorded immediately after the brain damage. Thus, there may be fundamental differences between the brain function of people who have brain lesions and people who do not, which mean that there are problems with applying findings from those with brain lesions to the general population.

Secondly, there are theoretical objections to paradigms that use dissociations and double dissociations (e.g., Bergeron, 2007; Dunn & Kirsner, 2003). Bergeron (2007) argues that the finding of a dissociation or double dissociation does not, by itself, show the presence of cognitive modules. Cognitive modules are specialised for a particular task, and a double dissociation is not evidence that there is specialization for a particular task, only that the workings of one cognitive task involves a brain area that another cognitive task does not, and vice versa. Thus, Bergeron argues that research on dissociations and double dissociations is best used in providing evidence for or against models of function or structure from cognitive psychology or neuroscience. This argument is problematic for the model of Peretz and Coltheart (2003), which largely uses evidence from cognitive neuropsychology to argue, for example, that separate modules are responsible for the processing of pitch and the processing of rhythm. Additionally, this argument is problematic for the Montreal Battery of Evaluation of Amusia (MBEA) (Peretz, Champod, & Hyde, 2003), which has individual tests for each part of the model of Peretz and Coltheart (2003). If, as Bergeron (2007) argues, cognitive neuropsychological evidence cannot by itself prove that cognitive modules are present, then the model of Peretz and Coltheart (2003) is circular and the MBEA is problematic.

Dunn and Kirsner (2003) make several arguments against the logic of dissociations and double dissociations. Firstly, they argue that it is impossible to show that there are pure dissociations between two mental functions, as there may be a large difference in mental function due to brain damage that is detected by task B, and an additional small difference in mental function due to brain damage that, due to compensation by other processes, is not detected by task A, though it is present. As such, Dunn and Kirsner argue that it may be more useful to characterise results of neuropsychological testing as positive and negative associations rather than dissociations. Secondly, they
argue that the underlying assumption of modularity in the logic of double
dissociations is unwarranted. ‘Lesioned’ connectionist models, which do not assume
modularity, appear to be able to mimic double dissociations (e.g., Plaut, 1995).
Thirdly, Dunn and Kirsner (2003) point out that dissociations are easily reified, with
two retrieval processes or codes, for example, explaining data as easily as the usual
explanation of two memory systems in the case of implicit and explicit memory.
Finally, Dunn and Kirsner point out that double dissociations could theoretically be
found between any two tasks, as no two tasks would lead to the exact same pattern of
neural activation. This shows the importance, as Bergeron (2007) argues, of largely
using neuropsychological research to test theories from cognitive psychology, as this
would require that dissociations are theoretically meaningful to some extent. Coltheart
as if they were experimental data, rather than as theories intended to parsimoniously
explain experimental data. Although double dissociations cannot be inferred from
data, they provide the best explanation of a large variety of data. One argument that
follows from Dunn and Kirsner (2003) is that researchers looking to argue for the
presence of double dissociations should use more than one task, and have different
levels of difficulty within those tasks, in order to test a particular mental function, to
maximise the likelihood that it is the purported mental function itself and not
extraneous variables related to the task that is affecting performance. Dunn and
Kirsner (1988) argue that research that uses different tasks of varying difficulty leads
to much stronger conclusions about the presence of dissociations between cognitive
modules.

3.3.1.2 The Montreal Battery of Evaluation of Amusia

Peretz and colleagues have argued that deficits in the discrimination of pitch changes
(such as melodic contour, interval magnitude, and scale) in melodies are an indicator
of amelodia, a form of amusia (Ayotte, Peretz, & Hyde, 2003; Ayotte, Peretz,
Rousseau, Bard, & Bojanowski, 2000; Liégeois-Chauvel, Peretz, Babaï, Laguitton, &
Chauvel, 1998; Peretz, 1990; Peretz, 1993). This series of experiments largely used
same-different discrimination tasks to test participants’ ability to detect changes in
pitch or temporal information, and are the experimental bases for the later
standardised test for amusia assembled as the Montreal Battery of Evaluation of Amusia (MBEA) (Peretz, Champod, & Hyde, 2003; Sloboda, Wise, & Peretz, 2005). The MBEA has four subtests, which test participants’ ability to detect changes to contour, interval, scale, rhythm, and metre in untransposed, unfamiliar melodies, along with a subsequent subtest testing participants’ ability to recognise melodies previously used during the testing period. The average interval magnitude between the contour change, interval change, and scale change is 4.3 semitones. A contour change denotes a change in direction (e.g., up instead of down). An interval change denotes a change in pitch interval size, though it is unclear whether the interval change is equivalent to changing from a step to a leap. Finally, a scale change denotes a change in the relationship between the changed note and the tonal centre of the melody (Krumhansl, 1990). The rhythmic changes in the MBEA are changes to the duration of two notes, such that the temporal grouping of notes into phrases within the melody has effectively been changed (Peretz et al. 2003); however, in some earlier research (Peretz, 1990, 1993), the rhythm task deleted melodic information, using only one pitch; additionally this task does not appear to have changes to temporal grouping boundaries. The metre task in the MBEA requires participants to correctly label waltzes (in the 3/4 time signature) and marches (in the 4/4 time signature). However, the metre task used in earlier research (Peretz, 1990, 1993) was a same-different task using waltz and march versions of a melody.

### 3.3.1.3 Congenital amusia

It has been argued that it is inappropriate to use the logic of dissociations and double dissociations to delineate evidence from developmental disorders, such as congenital amusia (Karmiloff-Smith, Scerif, & Ansari, 2003). Karmiloff-Smith et al. (2003) argue that developmental disorders caused by genetic mutations typically lead to widespread neural differences in most syndromes, though other faculties may superficially appear to be intact (e.g., Ayotte, Peretz, & Hyde, 2003). A study of identical and fraternal twins estimated that tone-deafness was 71% inheritable (Drayna, Manichaikul, De Lange, & Snieder, 2001). Thus, if congenital amusia is indeed congenital, then the assumption of anatomical modularity in comparison to normal controls is theoretically problematic. Additionally, Karmiloff-Smith et al.
(2003) argue that it is misguided to compare normal participants to those with developmental disorders without first being aware how the disorder develops across the lifespan. At present, the causes of congenital amusia are unclear – it has been argued that it could be a result of simply a result of disinterest in music (Hyde et al., 2006), or of problems with fine-pitch discrimination (Peretz & Hyde, 2003).

Furthermore, perhaps supporting the implication of the argument of Karmiloff-Smith et al. (2003) that there should be widespread neural differences in amusics compared to the normal population if the condition is congenital, it is currently unclear what neurophysiological differences are correlated with congenital amusia. An MRI study researching differences in gray matter between congenital amusics and control subjects (Hyde et al., 2006) was inconsistent with the hypothesis that fine-pitch discrimination problems is the primary cause of congenital amusia. The only consistent finding of Hyde et al. (2006) was that there were abnormalities in the right inferior frontal gyrus, an area that has been linked to the executive function of inhibition (Aron, Robbins, & Poldrack, 2004); in contrast, for example, the neural correlate of deficits in contour discrimination in participants with acquired amusia appears to be in the posterior superior temporal gyrus (Liégeois-Chauvel et al., 1998). The Hyde et al. (2006) study may have been confounded by the presence of different forms of amusia - they included congenital amusics both with and without arrhythmia, which would presumably have different patterns of differences in grey matter compared to control subjects. Thus, as the neural correlates of congenital amusia are unclear, and there is no widely accepted account of the development of congenital amusia, it is currently inappropriate to use data from congenital amusia to infer modularity using the logic of dissociations and double dissociations. However, whilst theoretically unlikely to be uninformative about adult memory for melodies, the existence of congenital amusia suggests a specific genetic basis for memory for melodies, and future genetic research on it may be informative.

3.3.2 Evidence of the Neural Structure of Memory for Melodies from Acquired Amusia
Acquired disorders caused by neural damage, for both theoretical reasons and based on current empirical knowledge, appear to be more informative than congenital amusia about the normal development of cognitive modules or processes involved in processing music. Thus, the next sections in this chapter will critically review evidence from acquired amusia for dissociations and double dissociations between the processing of different aspects of music. In particular I will examine dissociations between melodic contour and interval, pitch information (e.g., contour and interval) and rhythm, rhythm and metre. Additionally, I will examine evidence used to argue for a dissociation between language and music but an association between prosody and melody, which pertains to arguments in Chapter 2 about the relationship between the perception and cognition of language and the perception and cognition of music.

3.3.2.1 Dissociations between contour and interval discrimination

The evidence that there is a double dissociation between the processing of melodic contour and that of PIM is problematic. Using an early version of the MBEA paradigm, in which the scale change was replaced with a condition with a combination of transposed contour and PIM changes, Peretz (1990) tested 20 patients with brain damage to one hemisphere of the cortex caused by cerebrovascular disorder (e.g., stroke or aneurysm). Half the patients had left hemisphere damage (LHD) and half had right hemisphere damage (RHD), and these patients were compared with 20 controls without musical training. All participants, whether controls or amusics, were more accurate at detecting contour direction change than at detecting interval size change. Peretz argued that this was because interval processing was dependent on contour processing, as she conceives of contour processing as a global feature, and PIM processing as a local feature effectively filling in the gaps. Peretz (1990) additionally argues that the left hemisphere is responsible for the processing of interval information, where the right hemisphere is responsible for the processing of contour information. As support, she argues that she found a LHD patient with an isolated deficit for the interval size change condition, but no isolated deficit for the contour change condition. Liégeois-Chauvel et al. (1998) claim similar findings in a
study of patients who had acquired amusia as a result of unilateral temporal
cortectomies for the treatment of epilepsy.

However, there is an alternative interpretation of these results. Firstly, if the joint
accent structure hypothesis of M. R. Jones (1993) is accurate, changing one note so
that the contour changes, as Peretz (1990) and Liégeois-Chauvel et al. (1998) do, does
not change the global shape of the melody significantly more than changing one note
so that the PIM changes. Additionally, the contour change in these experiments
effectively also contain changes to both interval and contour; Peretz (1990) is careful
to change the pitch intervals in the contour stimuli in her study by similar amounts to
the pitch intervals in the interval stimuli. As such, contour changes in Peretz’s (1990)
stimuli are effectively also changes to PIM. Thus her finding of an isolated deficit for
the interval size change condition, but no isolated deficits for the contour change
condition, could be caused by the ability of patients with RHD to use interval
information to accurately discriminate between melodies in the contour change
condition rather than because interval information is dependent on contour
information. Additionally, although Liégeois-Chauvel et al. (1998) claim that their
results provide further evidence for Peretz’s hemispheric difference hypothesis, their
data appear to show both a LHD patient (Case 17) and a RHD patient (Case 54) with
normal scores on the contour task and subnormal scores on the interval tasks
(Liégeois-Chauvel et al. 1998, p. 1863). Furthermore, Ayotte et al. (2000) found two
cases where contour discrimination was below normal performance but interval
discrimination was not, in patients with acquired amusia as a result of surgery to
repair aneurysms on either the left or right cortex. One case had LHD and the other
had RHD. They found no cases where interval discrimination was below normal
performance but contour discrimination was not. Studying patients with unilateral
cerebrovascular lesions, Schuppert et al. (2000), used similar discrimination tasks to
Peretz and colleagues, but unlike MBEA-like stimuli, used contour changes that were
smaller in interval size than the interval changes. They found that LHD could cause
dissociation between interval and contour, but that RHD uniformly caused associated
deficits of interval and contour. The existence of Case 54 and the results of Ayotte et
al. (2000) and Schuppert et al. (2000) appear to contradict Peretz’s (1990)
hemispheric difference hypothesis. In summary, as both LHD and RHD can lead to
deficits in contour discrimination, and both LHD and RHD can lead to deficits in
interval discrimination, it is likely that the neural processes responsible for the discrimination of contour and interval are, at least, more complicated than Peretz (1990) has proposed. Until further cognitive psychology research delineates the processes responsible for contour and interval discrimination, no reliable dissociations can be found between contour and interval on the basis of cognitive neuropsychological research.

### 3.3.2.2 Dissociations between pitch discrimination and temporal discrimination

The evidence for the claim by Peretz and colleagues that there is a double dissociation between pitch discrimination and temporal discrimination is much stronger than that for a double dissociation between contour discrimination and temporal discrimination. Peretz (1990) claimed a double dissociation between pitch discrimination and temporal discrimination, with two patients unable to discriminate between melodies on the basis of changes to melodic contour, but able to discriminate between melodies on the basis of changes to rhythm, and two patients unable to discriminate between melodies on the basis of changes of rhythm, but able to discriminate on the basis of changes to melodic contour. Liégeois-Chauvel et al. (1998), using similar pitch discrimination tasks to Peretz (1990), but different temporal discrimination tasks, found several cases of amelodia without arrhythmia. Additionally, Ayotte et al. (2000) found several cases of amelodia without arrhythmia, and one case of arrhythmia without amelodia. Schuppert et al. (2000) found one case of amelodia without arrhythmia, and two cases of arrhythmia without amelodia. However, following Dunn and Kirsner (1988), an argument for a double dissociation is strengthened by the use of different tests, with different difficulty levels on individual patients; if there is a clear association between scores on different tests with different difficulty levels, then the case for a double dissociation becomes much stronger. With this rationale, Peretz and Kolinsky (1993) tested C.N., a patient with apparent amelodia but not arrhythmia, using both the usual MBEA stimuli and a Garner interference implicit memory task, where the patient had to discriminate rhythmic changes and ignore melodic changes. Where control participants were distracted by the presence of melodic changes in ‘same’ tasks, and aided by their presence in ‘different’ tasks, C.N. appeared to ignore
melodic changes in the ‘same’ tasks and was distracted by their presence in ‘different’ tasks. Thus Peretz and Kolinsky (1993) found convincing evidence, in both explicit and implicit tasks, of dissociation between pitch processing in melody and temporal processing in melody. Additionally, Di Pietro, Laganaro, Leemann, and Schneider (2004) presented a case of a musician with a left temporal-parietal stroke who had arrhythmia but not amelodia. They used the rhythm discrimination task in the MBEA along with other rhythmic tasks such as matching a heard rhythm to a visually presented score, and not only used the pitch discrimination tasks in the MBEA, but a variety of tasks to test pitch discrimination, such as score notation from memory and by ear. Thus there is convincing evidence that amelodia is possible without arrhythmia (Peretz & Kolinsky, 1993), and that arrhythmia is possible without amelodia (Di Pietro et al. 2004). This causes problems for the joint accent structure hypothesis of M. R. Jones (1993), which posits that the processing of melodic contour and rhythmic information is similar, unless one argues that melodic contour and rhythmic information are separately encoded but at some stage fused together; if so, one should expect some patients with brain lesions to show a dissociation between the ability to detect changes to melodic contour or rhythm, and the ability to detect changes to joint accent structure. In summary, neuropsychological research strongly suggests that different anatomical structures are responsible for the processing of melodic contour and rhythmic information

### 3.3.2.3 Dissociations between rhythm discrimination and metre discrimination

Evidence for a double dissociation between rhythm perception and metre perception is problematic. Firstly, problematically, the stimuli used to detect changes in metre in the MBEA and in experiments by Peretz and colleagues (e.g., Liégeois-Chauvel et al., 1998; Peretz, 1990; Schuppert et al., 2000) differs substantially from the stimuli used to detect changes in rhythm, contour, interval or scale. Where participants have to determine whether two melodies are the same or different in all other tasks, the metre perception task in the MBEA requires participants to name the stimuli as either a march or a waltz. Additionally, in the studies by Liégeois-Chauvel et al. (1998) and Schuppert et al. (2000), the metre perception task is polyphonic, so that listeners can
use not only durational information but also harmonic information to determine the metre – Peretz (1990), however, used a monophonic metre perception task. The task would be more suitable if the melodies with changes to rhythm involved listeners being able to use harmonic information to determine the rhythm. Thus, as the MBEA has only one metre task and only one rhythm task, any dissociations found by these tasks could potentially be a result of these substantially different task requirements (Dunn & Kirsner, 2003) rather than a result of a dissociation between metre and rhythm. For example, any difference in such studies could be a result of poor processing of harmonic information, or polyphony, or could be the result of neural differences between discriminating between melodies and naming marches and waltzes. Additionally, there appears to be no published melody discrimination task that has systematically manipulated metre, let alone systematically manipulating metre under conditions of transposition. Therefore it is unclear whether metre is salient to memory for melodies, let alone whether the stimuli in the MBEA are appropriate. Thus any arguments for dissociations between two cognitive modules responsible for metre and rhythm are likely to be problematic.

It has been argued that there is a double dissociation between the processing of metre and the processing of rhythm, but this argument is unjustified. Peretz (1990) found patients with deficits in the rhythmic discrimination task but not in the metric perception task. Liégeois-Chauvel et al. (1998) additionally found patients with deficits on the metric perception task but not on the rhythmic discrimination task, and claimed that their results and that of Peretz (1990) together suggested a double dissociation between rhythm and metre. However, considering that Peretz (1990) used monophonic stimuli and Liégeois-Chauvel et al. (1998) used polyphonic stimuli in the metre task, it is additionally plausible that the patients with deficits on the metric perception task in the Liégeois-Chauvel et al. study had deficits to perception of polyphony rather than deficits to metric perception, and thus the conclusion that there is a double dissociation is unjustified, even without considering the abovementioned problems with the stimuli.

Other researchers, using less problematic metric stimuli, have reported data suggestive of a dissociation between metre and rhythm. Di Pietro et al. (2004) found deficits in rhythmic discrimination but not in metric discrimination, and used a variety
of different tests of the processing of rhythm and metre, rather than just same-different judgements. Additionally, Schuppert et al. (2000) found a double dissociation between deficits in metric perception and deficits in rhythmic discrimination, using a same-different judgement for both conditions. Although the double dissociation found by Schuppert et al. (2000) constitutes stronger evidence than that of Peretz and colleagues, Schuppert et al. (2000) only used one form of test of deficits in metre, and one form of test of deficits in rhythm. Thus, following the logic of Dunn and Kirsner (1988), it is possible that deficits related to the task, rather than to the perception of rhythm or metre, contributed to the finding of dissociated deficits. In summary, there is some evidence that there is a dissociation between rhythmic discrimination and metric discrimination, in that Di Pietro et al. (2004) found evidence of rhythmic deficits without metric deficits, and weaker evidence for the reverse dissociation. As such, a double dissociation between the cognition of metre and the cognition of rhythm is possible, but has not been determined definitively.

3.3.3 Evidence about the Relationship between Music and Language from Acquired Amusia and other Disorders

Some research has analysed the relationship between memory for melodies and memory for prosody to determine whether there is a dissociation. Patel (2003) has argued that music and language share short term processing resources, but have separate representations in long term memory. Patel et al. (1998) studied two patients, C.N., and I.R., with brain lesions due to aneurysms. C.N. (Peretz & Kolinsky, 1993) had bilateral lesions to the superior temporal gyrus, though not to Heschl’s gyrus, and limited damage to the right inferior frontal gyrus. In contrast, I.R. had more extensive damage; in the left hemisphere, I.R. had extensive damage to the superior temporal gyrus, including Heschl’s gyrus, and in the right hemisphere, extensive damage to the superior temporal gyrus, but not including Heschl’s gyrus. Additionally, I.R. had extensive damage to the inferior and middle frontal gyri. Patel et al. (1998) designed a discrimination task where participants had to distinguish French sentences on the basis of prosodic features of speech. One condition had statements distinguished from questions on the basis of the presence of a rise in pitch at the end of the sentence,
whereas a second intonation-based condition had a change in the focus of a sentence (e.g., ‘take the train to Bruge, Anne’ compared to ‘take the train to Bruge, Anne’). There was an additional temporal-shift task where the rhythm of a sentence was altered (e.g., ‘Henri, the small one, eats a lot’ compared to ‘Henri, the small one eats a lot’). These conditions were compared to musical conditions where the prosodic features of sentences were translated into non-metric, atonal melodies, by altering the fundamental frequency of the sentences used in the prosodic features condition so that they became standard musical pitches. C.N. and I.R. were compared to matched controls. C.N. was not significantly different to controls on any task, but I.R. performed at chance level on the focus-shift task and the rhythmic discrimination task in both linguistic and musical stimuli. Although the extent of their lesions differed, neither I.R. nor C.N. performed differently on linguistic compared to musical stimuli. Patel et al. (1998) interpreted these findings to be that C.N. had deficits in long term memory for music, but not long term memory for speech (e.g., she could not remember familiar melodies but could remember words) and I.R. had both deficits in long term memory for music and short term memory for music, and deficits in short term memory for prosodic information. Additionally, I.R. appears to have deficits in working memory tasks such as digit span (Belleville, Caza, & Peretz, 2003) which suggests an impaired phonological loop (c.f., Baddeley, 2000).

There are mixed results in other studies of the relationship between amusia and deficits in the discrimination of prosody. Nicholson, Baum, Kilgour, Koh, Munhall, and Cuddy (2003) tested K.B., who appeared to have acquired amusia after extensive right hemisphere damage due to a stroke, using a similar paradigm to Patel et al. (1998). K.B. had normal memory function and language ability, but performed at chance in processing both prosodic and melodic material. Nicholson et al. (2003) argue that the pattern of damage and behaviour is consistent with the hypothesis of Patel et al. (1998) that there is dissociation between short term memory and long term memory for music, and an association between short term memory for prosody and short term memory for melodic contour. In contrast, though, Piccirilli, Sciarma, and Luzzi (2000) studied a patient who appeared to have impaired melody discrimination but intact prosodic discrimination, though they did not test the abilities of their patient in this regard as systematically as Patel et al. (1998).
It is possible that other patients with acquired amusia may not exhibit the same association between prosodic processing and melodic processing. Both K.B. and C.N. have extensive damage to large areas of the cortex. There is evidence that congenital amusia differs from acquired amusia in that there is no association between performance on linguistic stimuli and musical stimuli in the Patel et al. (1998) paradigm; Ayotte et al. (2002) found that congenital amusics were not significantly different to controls with linguistic stimuli, but were significantly poorer at the task using musical stimuli. Similar research by Patel, Foxton, and Griffiths (2005) supported the findings of Ayotte et al. (2002), suggesting that deficits in discriminating musical stimuli in people with congenital amusia are not due to deficits in the ability to detect changes in pitch.

Given Patel’s (1998, 2003) hypothesis that there is shared short term processing of prosodic and musical stimuli, it is instructive to view the shared incidence of acquired amusia and short term memory deficits. Of those studies of acquired amusia that tested short term memory ability, the patient with atonalia studied by Peretz (1993), the RHD patients studied by Liégeois-Chauvel et al. (1998), C.N. (Peretz & Kolinsky, 1993; Patel et al., 1998) and the patients studied by Ayotte et al. (2000) had no deficit when they were given tests of short term memory such as the Weschler Memory Scale. In contrast, I.R. (Patel et al., 1998; Belleville et al., 2003), D.L. (Di Pietro et al., 2004) and the LHD patients studied by Liégeois-Chauvel et al. (1998) had deficits on tests of short term memory such as the Weschler Memory Scale. There thus appears to be no clear relationship between memory deficits and deficits in any specific musical task such as contour discrimination.

3.3.4 Conclusions from the Study of Acquired Amusia about Relational Memory for Melodies

In conclusion, the literature on acquired amusia shows strong evidence for a double dissociation between arrhythmia and amelodia, suggesting that there are separate brain areas that are involved in the processing of melodic contour but that are not involved in the processing of rhythm. Similarly, the neuropsychological literature shows that rhythmic deficits are possible without metric deficits, suggesting that some
separate neural structures that are involved in the processing of rhythm are not involved in the processing of metre. Evidence for the reverse dissociation, however, that metric deficits are possible without rhythmic deficits, is weaker. In contrast to these stronger findings, the evidence regarding dissociations between contour and interval processing is weak and conflicted, as is the evidence regarding associations between working memory and the processing of pitch in melodies and the processing of prosodic information in speech.

3.4 Evidence of the Neural Structure of Memory for Melodies from Neuroimaging Techniques

3.4.1 Evidence from Event-Related Potential Studies

There have been several studies using a task involving the discrimination of melodies based on pitch that have analysed event-related potentials (ERPs; Schiavetto, Cortese, & Alain, 1999; Tervaniemi, Castaneda, Knoll, & Uther; 2006; Tervaniemi, Rytkönen, Schröger, Ilmoniemi, & Näätänen, 2001; Trainor, Desjardins, & Rockel, 1999; Trainor, McDonald, & Alain, 2002). ERPs are an averaged electric wave calculated by averaging multiple EEG scans from the same participant to the same stimuli. EEG scans, and thus the findings of ERP studies, are temporally accurate to the millisecond, but spatially inaccurate beyond suggestions, for example, that the ERP is frontally located. Common ERPs found in ERP studies using auditory stimuli include Mismatch Negativity (MMN), the N2 and the P3. The MMN (also called the N2a) is a frontally-located negative potential occurring automatically after 150-250ms in response to a change to an auditory stimulus (Picton, Alain, Otten, Ritter, & Achim, 2000). The N2 (also called N200 or N2b) is a negative potential occurring between 150ms-250ms after a change in an auditory stimulus, whereas the P3 (also called P300 and P3b) is a positive potential occurring between 300-700ms after a relevant stimulus; both the N2 and P3 are thought to be elicited by conscious attention (Picton et al., 2000; Portin, Kovala, Polo-Kantola, Revonsuo, Muller, & Matikainen, 2000).
Evidence from ERP studies suggests that there is little difference between the automatic processing of contour and interval changes, but that the conscious processing of contour appears to be quicker than the conscious processing of interval, perhaps because of easier categorization of changes. An ERP study by Schiavetto et al. (1999) examined nonmusicians consciously discriminating between contour changes and interval magnitude changes, based on the tasks used by Peretz (1990). They found a larger N2 and an earlier P3b onset for contour changes than for interval magnitude changes, which they interpreted to mean that the contour changes lead to a greater mismatch than the interval changes; Trainor et al. (2002) argue that this could also be interpreted as having to do with the difficulty of categorizing the stimuli. Trainor et al. (1999) compared musicians and nonmusicians on their ability to discriminate contour and interval changes in 5-note melodies concurrently with an ERP study, focusing on the P3 component. They found no significant difference between musician and nonmusician participants in the latency or strength of the P3 component during the discrimination of changes to melodic contour. However, interval changes led to more delayed and weaker P3 waves in nonmusicians. It should be pointed out that Trainor et al. (1999) transposed interval changes within melody pairs but did not transpose contour changes within melody pairs, as so the ability of the weaker P3 waves in nonmusicians may be due to the transposition rather than due to the interval changes. Additionally, in their statistical analysis, Trainor et al. (1999) did not distinguish between the ERPs corresponding to different kinds of interval changes. In the interval change condition, they made changes that could be interpreted as alterations to scale rather than interval (e.g., either a flat fifth or a minor in a major scale) as well as changes that could be interpreted as changes to the implied harmony of the piece (e.g., ending on a G rather than on an F in the key of C). Given that musicians use changes in implied harmony in similarity judgments, but nonmusicians do not, suggesting that musicians are more sensitive to implied harmony (Schubert & Stevens, 2006), it may be that the difference between musicians and nonmusicians on the interval condition is due to musicians being more sensitive to differences in scale or implied harmony in the melodies. This point is especially germane because Trainor et al. (1999) were specifically examining the role of conscious attention in melody perception by examining the P3 rather than MMN; trained musicians presumably have more experience in the conscious comparison of melodies. In a follow-up study, Trainor et al. (2002) experimentally compared automatic and conscious controlled
processing of contour and interval changes using similar stimuli to Trainor et al. (1999); in one condition, nonmusician participants were instructed to read a book and ignore the stimuli, whereas in a second condition participants actively discriminated melodies. Trainor et al. (2002) found an MMN when participants ignored the stimuli for both contour and interval, suggesting that changes to contour and interval are both processed automatically; the magnitude of the MMN was similar for contour and interval, and there were no significant differences between contour and interval in the delay between the stimuli and the MMN. Additionally, they found a larger MMN for interval stimuli with an interval of a whole tone rather than an interval of a semitone. Tervaniemi et al. (2006) found similar results, using a mismatch negativity paradigm to assess the ability of nonmusicians and performing musicians without formal training to automatically detect changes in contour or interval in a 5-note melody.

In summary, ERP studies suggest that the cognition of melodic contour and pitch interval in memories can be the result of implicit (e.g., MMN) or explicit (e.g., P3) processes. Additionally, there is some uncertainty about the role of musical training in the cognition of interval, in particular; although Trainor et al. (1999) found that musicians were more sensitive to interval than nonmusicians in a conscious attention paradigm, other studies using implicit processes suggest little difference (e.g., Tervaniemi et al., 2006). However, studies have varied in terms of the interval used, and no study has forced participants to use a relational code for melodies by using the transposition of melodies between the target and comparison melodies. As such, ERP studies are inconclusive in regards to what they can tell us about the functioning of memory for melodies.

### 3.4.2 Evidence from Spatially Accurate Neuroimaging Techniques

At the current time, there is no available published research using spatially accurate neuroimaging techniques such as fMRI or PET that has conclusively identified any neural architecture that corresponds to short term memory for melodies. However, a small amount of research has found some form of activation related to participants listening to melodies. In a PET study measuring cerebral blood flow, Zatorre, Evans,
and E. Meyer (1994) examined memory for individual pitches rather than memory for melodies; however, in a condition where the pitches were part of a melody rather than presented alone, there was a significant amount of cerebral blood flow to the frontal operculum, suggesting that the frontal operculum has some role in melody perception; alternatively, such activation could be interpreted as having some role in the inhibition of attention to the melody so that the individual pitches could be attended to. Griffiths, Buchel, Frackowiak, and Patterson (1998) examined the perception of pitch and time in either isochronous diatonic melodies or isochronous monotones using an MRI study. They found bilateral activation in the anterior and superior temporal cortices when there were diatonic melodies, suggesting that these brain areas play a role in the perception of melodies. An fMRI study by Patterson, Uppekamp, Johnsrude, and Griffiths (2002) using similar stimuli appeared to show that the superior temporal gyrus played some role in the perception of diatonic melodies. However, none of Zatorre et al. (1994), Griffiths et al. (1998), or Patterson et al. (2002) used methods which specifically analysed relational memory for melodies (e.g., transposition), and it is possible in all of their paradigms that it is the perception of pitch or timbre, for example, that is causing activation, rather than the perception of melody per se.

The uncertainty about the neuroanatomical location of neural structures involved in memory for melodies – which notably adds to the uncertainty from cognitive neuropsychological studies of amusia – leads to the conclusion that spatially accurate neuroimaging is, as yet, not informative about the cognitive structure or function of memory for melodies. Indeed, although future research using techniques like fMRI may detect areas of the brain that are associated with different aspects of memory for melodies, it is unclear whether it is possible for neuroimaging studies to be informative about the function of memory for melodies. Coltheart (2006a, 2006b) argues that, though neuroimaging studies have provided information about which brain areas are associated with particular cognitive tasks, there is no conclusive evidence that neuroimaging has been informative about any cognitive function. Coltheart argues that this neuroimaging research is not informative about cognitive function because few cognitive theories actively and specifically nominate particular brain areas as being involved in a particular cognitive function, a necessary precondition for neuroimaging studies to be informative about cognitive functions.
3.5 Conclusions about Memory for Melodies

What conclusions can be drawn from the diverse literature involving relational memory for melodies? Firstly, this literature confirms that melodic contour is highly salient to the memory for melodies of both infants and adults across several tasks. However, it also shows that there are apparent limits to the salience of melodic contour. It is more salient in melodies that are shorter, slower, and less tonal, that have been heard more recently, and that are less familiar. The literature also shows that melodic contour cannot be understood except with reference to other aspects of melody for memories, as the presence of tonality affects the perception of melodic contour in complex ways (e.g., Dowling, 1991), as does the presence of durational information (M. R. Jones, 1993). As such, the literature suggests that it may be memory for melodies rather than the cognition of melodic contour that is the evolved neural mechanism.

Secondly, it appears that the relationship between melodic contour and interval size, in particular the relationship between melodic contour and PIM, is unclear, because no widely available published research has either transposed melodies or systematically looked at the role of LTM information in memory for PIM. The neuropsychological literature that claims there are dissociations between memory for melodic contour and memory for PIM is additionally problematic on closer examination. Additionally, neuroimaging data does not at present differentiate between the neural location of the processing of melodic contour and the processing of PIM. The simplest explanation of the relationship between melodic contour and PIM is that memory for melodic contour and memory for PIM are both components of dynamic pattern structure. However, at present, the cognitive relationship between interval magnitude and melodic contour is an empirical question, and one with theoretical implications for researchers in music cognition. Firstly, if interval magnitude and melodic contour are the result of similar neural mechanisms, it suggests that the theorizing about the evolutionary role of the cognition of melodic contour is more appropriately theorizing about the evolutionary role of memory for pitch accent structure. Secondly, if interval magnitude and melodic contour are shown
to be the result of similar neural mechanisms, it suggests that recognition tasks that
differentially use melodic contour and PIM for purposes such as the diagnosis of
amusia are misguided.

Thirdly, it appears that memory for melodic contour and memory for rhythmic
structure interact in various ways, in that changes in pitch accent structure can confuse
listeners about the rhythmic accent structure, and vice versa. This suggests that both
duration information and pitch information are used in the chunking of melodies that
must occur as a result of short term memory processes which are limited in the
amount of chunks that can be held at any one time. However, there is reasonably good
neuropsychological evidence for a double dissociation between memory for melodic
contour and memory for rhythm. There is some evidence that there may be separate
perceptual encodings of melodic contour and rhythm that are later combined into a
memory representation (e.g., Peretz & Kolinsky, 1993). However, it is unclear how
memory for pitch and memory for durational information are related, because of the
lack of transposition and lack of systematic variation of ISIs or melody length in
melody discrimination tasks researchinig durational information. Research that
specifically looks at the role of memory for melodies in the chunking of durational
and pitch information will be informative as to the function of memory for melodies.

Fourthly, and finally, a review of the neuropsychological literature combined with a
review of the music cognition literature on melodic contour suggests that the evidence
for the presence of shared resources for processing language and processing music but
separate representations of language and representations of music (e.g., Patel et al.,
1998) is currently surprisingly weak, as it is possible that the hypothesis derives from
a misinterpretation of neuropsychological data from a patient who coincidentally has
damage to, firstly, working memory areas of the brain and, secondly, separate areas of
the brain that process memory for melodies. Thus, at present, the relationship between
working memory and memory for melodies is unclear, and would be benefited by
behavioural cognitive psychology research specifically testing Patel et al.’s (1998)
hypothesis.
CHAPTER 4

*Conceptual Requirements of a Model of Memory for Melodies*
4.1 Introduction

Whereas Chapter 3 of this thesis focused on what information is processed in memory for melodies, Chapter 4 will focus on how information is processed in memory for melodies. It will be argued in Chapter 4 that it is necessary to construct a new cognitive model of memory for melodies in order to adequately explain how information is processed by memory for melodies. In particular, as most research that has investigated memory for melodies uses STM tasks in the auditory modality, the hypothesis that verbal-short term memory (vSTM) and memory for melodies are cognitively equivalent (e.g., Schendel & Palmer, 2007; Williamson, Baddeley, & Hitch, 2006) will be evaluated in detail. The resolution of this argument will have major implications for any attempt to explain how information is processed by memory for melodies. Section 4.2 of this chapter outlines theoretical and empirical issues to do with comparing memory processes that are involved in memory for lists of words to those involved in memory for melodies. Section 4.3 of this chapter will summarise current knowledge of memory processes involved in verbal serial recognition tasks and will assess the evidence that these processes have equivalents in memory for melodies. Section 4.4 assesses the capacity of vSTM models to account for memory for melodies. Section 4.5 assesses the capacity of specific models of STM for music to account for memory for melodies. Section 4.6 will conclude by listing the phenomena that a model of memory for melodies must be able to explain.

4.2 Similarities and Differences between the Serial Recognition Task and the Melody Discrimination Task

Evaluating the cognitive similarity between vSTM and memory for melodies is necessary because of the similarities in tasks, modalities, and research findings. Firstly, both tasks investigating memory for melodies and tasks investigating verbal short term memory tasks typically use temporally spaced stimuli that have to be remembered in some form. Secondly, both kinds of tasks often use auditory stimuli, whether spoken words or, for example, melodies played using a piano; it should be
noted, however, that visually presented stimuli are more common in vSTM tasks. Thirdly, recent research has suggested that vSTM and memory for melodies may be cognitively equivalent (Schendel & Palmer, 2007; Williamson, Baddeley, & Hitch, 2006; see Section 4.3.2.1 for more detail), and recent research into memory for melodies has attempted to explain results in terms of models of memory (Dowling et al., 2002). If memory for melodies is merely a function of verbal short term memory, then theories of verbal short term memory have important implications for those wishing to understand the evolutionary psychology of music; if vSTM is largely responsible for the manner in which humans discriminate melodies, then it is likely that music is, as Pinker (1997) proposed, auditory cheesecake, rather than being evolutio

These differences between the use of melodies and the use of lists of words as stimuli in discrimination tasks. The standard task used in experiments analysing memory for melodies is the melody discrimination task (see Section 3.2). In contrast, the most commonly used task in experiments that investigate vSTM is the serial recall task, wherein participants hear one list of words or digits, and then have to recall, in order, the list of words (e.g., D. Jones, Macken, & Nicholls, 2004). However, another typical task in research investigating vSTM is the serial recognition task, wherein participants have to correctly discriminate whether the first list of words contains the same words, in the same order, as a second list of words. Word lists are presented either auditorily or visually. There appears to be consensus amongst researchers investigating vSTM that vSTM models should be able to explain results from experiments using serial recognition tasks, and that serial recognition tasks access vSTM (Gathercole, Pickering, Hall, & Peaker, 2001; Jeffries, Frankish, & Lambon Ralph, 2005; Nimmo & Roedenslays, 2005; Tulving & Watkins, 1973). Thus, apart from some differences between melodies and lists of words, the serial recognition task with auditory presentation is essentially equivalent to the melody discrimination task. However, where there is transposition between melodies

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within melody pairs in a discrimination task there are further differences between the
tasks; no equivalent of transposition is typically used in serial recognition tasks.
However, this does not refute the essential similarity of the two tasks; some research
on verbal short term memory has used serial recognition tasks with altered stimuli.
For example, the list probe task used by Henson, Hartley, Burgess, Hitch, and Flude
(2003) used the visual presentation of letters, and can be interpreted as presenting the
first list temporally and the second list spatially. As the presentation of the second list
is different to the presentation of the first list, this task may be closer to the melody
discrimination task than the serial recall task in some respects, despite its visual rather
than auditory presentation. Nonetheless, these differences are not large enough that
Henson et al. (2003) consider their list probe task to be measuring a different
cognitive process; they interpret their results as having implications for theories of
vSTM. Thus, if the serial recognition of word lists and the serial recall of word lists
both test the same cognitive process (e.g., vSTM), and the serial recognition of word
lists and melody discrimination tasks are essentially equivalent, memory for melodies
may simply be a function of vSTM.

Differences between word lists and melodies cause problems for the argument that
memory for melodies is a function of vSTM. Where the list of words in serial
recognition or recall tasks usually ensures that words in a list are semantically and
syntactically unconnected with each other (e.g., ‘hat, book, pen, rat, rug, pig, hen’,
from Mueller, Seymour, Kieras, & D. Meyer, 2003), melodies are, as J. Davies (1979)
points out, integrated wholes. The individual words in a word list used in a serial
recognition task usually carry denotative meaning but the list of words itself usually
has no coherent meaning. In contrast, the individual notes of a melody do not usually
have denotative meaning, but Huron (2006) argues that the combination of notes
implies a connotative emotional meaning even in melodies that are atonal and novel
to the listener. If this emotional meaning is automatically elicited by a combination of
notes, then it is problematic for the argument that vSTM and memory for melodies are
similar; if emotional meaning is present in novel atonal melodies, word lists and
melodies are fundamentally different kinds of stimuli, as melodies are implicitly
syntactic in a way that word lists are not. Additionally, LTM knowledge drawn on by
processes involved in syntax in music appear to be substantively different to LTM
knowledge drawn on by processes involved in syntax in language (Patel, 1998, 2003),
due to the different ways in which music and language are used. This causes problems for the hypothesis that vSTM, widely thought to be language-specific and reliant on linguistic perception and cognition (Baddeley et al., 1998; Gupta & MacWhinney, 1997), is also responsible for processing music. Models attempting to explain memory for melodies thus need to address the presence of syntax in melodies, and address the difference between LTM processes involved in music compared to those involved in language, before they can explain memory for melodies.

4.3 Aspects of Memory That May Play a Role in Memory for Melodies

Before examining the aspects of human memory that may play a role in memory for melodies, it is first necessary to address some theoretical issues regarding human memory. The standard, although still controversial, view is that human memory has at least three separate 'stores' from a temporal viewpoint - sensory memory, short term memory, and long term memory (R. Atkinson & Schiffrin, 1971; Baddeley, 1997). It appears, however, that there is at least a considerable amount of interaction between different stores (e.g., Burgess & Hitch, 2005; Winkler & Cowan, 2005). Some have argued that there are considerably more than three separate stores of information (Vallar, 2006), whereas others claim that separate memory stores do not actually exist (Macken & D. Jones, 2003; Nairne, 2002).

Neuropsychological evidence for double dissociations between vSTM and LTM is often used to justify the separation of vSTM and LTM in separate store theories such as that of Baddeley (2000). For example, the patient described by Shallice and Warrington (1970) performed poorly at vSTM tasks but had average performance on LTM tasks (see Vallar, 2006, for a summary of such evidence). However, Rangarath and Blumenfeld (2005) have argued that most neuropsychological studies used in arguments for double dissociations do not have equivalent tasks for vSTM and LTM or are not testing equivalent areas of memory; a criticism of their position is that different tasks would be expected to be better indices of LTM and vSTM processing, as each form of memory is used in different ways. Neuropsychological studies that use more equivalent tasks find weaker evidence for double dissociations. This may
provide more support for activation-based models of memory (Macken & D. Jones, 2003; Nairne, 2002). However, although the amount to which vSTM and LTM are dependent on the same processes is unclear, it is clear that LTM information interacts with attention and perceptual processes; theories that attempt to explain immediate memory for verbal material reflect this. In Nairne’s (2002) model, for example, the interaction of attention with LTM is thought to account for the effects and findings which are associated with Baddeley’s (2000) concept of the phonological loop. Whether STM and LTM stores are involved, the melody discrimination task largely used to determine the nature of memory for melodies still requires the comparison of incoming auditory information with previously heard auditory information. This ability is limited in temporal capacity and requires perceptual forms of memory such as auditory memory, and knowledge of the pitch and temporal expectancies associated with a number of aspects of music.

### 4.3.1 Auditory Memory

It has been argued that, in the auditory modality, there is some form of sensory store, which is modality-specific, not dependent on attention, and which holds a short finite amount of information with a fine resolution (Winkler & Cowan, 2005); this store is typically referred to as auditory memory or echoic memory. Cowan (1984) argues that there is evidence for two separate stages of auditory memory processing. The first stage of auditory memory is short auditory storage, which is literal, experienced as sensation, and which lasts for between 150 ms and 350 ms. Short auditory storage is unanalysed, and subject to interference as information is overwritten. Evidence for short auditory storage largely comes from paradigms that examine the way that sensory information is integrated or combined, such as that of Plomp (1964). In one condition of Plomp’s experiment, participants listened to two separate bursts of different intensity, the first louder than the second; the two bursts together lasted for 400 ms, including a variable gap between the bursts. When the variable gap was shorter than 200 ms, participants did not notice it. This suggests that the capacity of short auditory storage is 200 ms, as the just-noticeable difference in other experiments can be as little as 30 ms (e.g., Penner, 1977). What is occurring in Plomp’s (1964)
experiment, according to Cowan (1984), is that the second burst is interpreted as a continuation of the first burst only if the first burst is still in short auditory storage.

In comparison to short auditory storage, Cowan (1984) argues that there is a longer form of sensory memory, which he terms long auditory storage. This form of memory storage appears to be auditory in nature and appears to last for up to 20 s. Unlike short auditory storage, long auditory storage is not literal but is experienced as memory. Information in long auditory storage is at least partly categorised, and subject to cognitive processes such as attention (Keller, Cowan, & Saults, 1995). Secondly, it has been shown that long auditory storage is not entirely a pure record of sensory experience, but rather has been encoded along Gestalt principles of organisation (Dowling, 1973). The existence of this store, or some process equivalent to it, is supported by evidence from a variety of paradigms, such as discrimination tasks (e.g., Crowder, 1982), partial report tasks (e.g., C. J. Darwin, Turvey, & Crowder, 1972), and suffix effects; this store is most relevant to short term memory for melodies in that a duration of up to 20 s could potentially account for differences in melodies of those lengths; in this chapter, this store shall be generally referred to as auditory memory or pitch memory.

Experiments that use the partial report of auditory stimuli support the existence of some form of short term memory for uncategorised auditory information. In the C. J. Darwin et al. (1972) experiment, participants listened over headphones to a voice saying a combination of letters (e.g., B) and digits (e.g., 9) at the rate of 3 syllables per second. Participants heard three lists of three items simultaneously; one list was heard only through the left ear, one list was heard only through the right ear, one list was heard in both ears, giving the impression of three separate auditory locations. Darwin et al. measured participants' ability to report as many of the words heard through one auditory location ('partial report'). Additionally, participants were required to wait until a visual cue appeared before they could respond, and there were delays of 0, 1, 2, or 4 seconds. In partial report, they found that participants were significantly better at detecting the third item in a list compared to the first or second item in a list. They additionally found that a longer delay between presentation and response led to less accurate performance. Further experiments reported by Darwin et al. (1972) showed that this store was not affected by long term memory knowledge.
about semantic categories, suggesting that it was not a categorical store but held information in an acoustic form.

Similarly, it has been argued that same-different discrimination tasks using auditory stimuli reflect the existence of long auditory storage. Crowder (1982) examined participants’ ability to discriminate between stimuli that were derived from synthetic voices with fine gradations between the vowels in “bit” and beet” (e.g., between two presentations of /i/, one of which was slightly more like /ee/ than the other), with delays between the first and second presentation that ranged from 0s to 5000ms; Crowder argued that participants could not categorise the difference between the vowels, as both vowels would be categorised as /i/, and thus categorisation memory – that is, vSTM – could not be used. Crowder found that participants had a good rate of vowel discrimination at 5000ms, though there was some decay in performance compared to smaller delays (e.g., 400ms). Insofar as vSTM is categorical and verbal in nature and long auditory storage is partly uncategorised and auditory, this suggests a difference between vSTM and long auditory storage.

4.3.1.1 The Role of auditory memory in memory for melodies

Auditory sensory memory appears to be an early stage in memory for any auditory material, and, as such, it is likely that it plays a role in memory for melodies and music in general. It is currently unclear, however, whether there are different auditory memory systems for pitch and music. Deutsch (1975) posits a kind of memory, pitch memory, that resembles Cowan’s (1984) concept of long auditory storage, and that specifically processes tones in an absolute manner (compared to the relational manner in which melodies are processed). Deutsch (1975) argues that memory for pitch must be memory specifically for pitch, as the accuracy of memory for pitch decreases more after participants hear interfering tones than after participants hear interfering words. However, as Cowan (1984) argues, there is some analysis of information in auditory memory, and this analysis may include judgements about whether auditory stimulus is music or speech. Therefore, as it is currently unclear whether there are separate auditory memory processes for language, environmental sounds, and music, I will
refer to memory for musical information as pitch memory\(^7\). In any case, musical materials like melodies are subject to auditory perception processes in auditory memory. For example, Dowling (1973) found that listeners separated melodies with notes alternating between two octaves into two separate streams, which suggests that basic auditory perception processes (c.f., Bregman, 1990) play a role in the perceptual organisation of melodies. Thus, insofar as melodies presented auditorily must first pass through auditory memory, where they are encoded in certain ways, auditory memory appears to play a role in memory for melodies.

Additionally, the ability to access pitch memory appears to facilitate recall in tasks that involve memory for melodies. The use of transposition in a melody discrimination task is thought to prevent participants from using pitch memory to aid recall (Dowling, 1978). Experiments that compare the discrimination of melodies with transposition to the discrimination of melodies without transposition find that accuracy is lower with transposition (Dowling & Fujitani, 1971; Peretz, 1990), suggesting that, when available, information from pitch memory can be used to discriminate between melodies. In summary, pitch memory appears to play two separate roles in the encoding of memory for melodies. Firstly, it contributes to the perceptual organisation of melodies. Secondly, traces in pitch memory, which can last for up to 20 s under the right circumstances, can be used to facilitate the discrimination of melodies if the melody discrimination task does not use transposition. A model of memory for melodies must therefore provide some explanation of how pitch memory and memory for melodies interact, and in particular has to be able to explain how pitch memory and memory for melodies interact in melody discrimination tasks.

### 4.3.2 Verbal Short-term Memory

Humans appear to be able to hold a small amount of manipulable verbal information in a categorical form, for immediate uses such as recognition or recall; this capacity is vSTM. Nairne (1990, 2002) and Baddeley (2000) disagree on the neural bases of

\(^7\) Pitch memory is the term used by Deutsch (1975), and it should be pointed out that pitch memory presumably also holds information other than pitch relevant to music, such as timbre and duration.
vSTM, but do agree that the capacity for remembering things over short periods of
time has, at least, the following characteristics. Firstly, they agree that the capacity to
hold verbal information for immediate use is limited. Secondly, they agree that this
capacity limitation is temporal in nature. Thirdly, they agree that this capacity appears
to be largely based around verbal information. Fourthly, they agree that this capacity
can use information from long term memory. Finally, they agree that there is some
ability to chunk information in order to maximise capacity.

The basic capacity of vSTM appears to be about three to five chunks of information,
and this capacity limit appears to be temporal in nature. Although a vSTM capacity of
five to nine chunks of information is often cited (G. A. Miller, 1956/1994), Cowan
(2000) reviewed experiments that suppressed the ability to use the amount of
information within a chunk to maximise memory span, by methods such as
articulatory suppression (i.e., requiring participants to verbally repeat “the” or “blah”
while the list of words is presented), and concluded that the majority of experimental
research in this area seemed to show that humans have the capacity to remember three
to five chunks of information. Additionally, this capacity is temporal in nature, as
increasing the temporal length of words decreases the ability to remember the words –
for example, recall of “cap” would be better than recall of “cape” (Baddeley,
Thomson, & Buchanan, 1975). This word length effect suggests that there is some
temporal capacity limit to STM.

It may be theoretically problematic to claim that vSTM is phonological. Phonology is
the study of sound as used in language, and includes the study of pitch in language. In
tonal languages such as Mandarin, changing the pitch contour with which a word is
said can dramatically change the meaning of a syllable; for example, in Mandarin,
“ma” said with a long, high, level tone means “mother”, whereas “ma” said with a
tone rising from a low pitch to a high pitch means “hemp”. Similarly, intonation in
English affects meaning – questions are said with a different intonation to statements,
for example. Baddeley claims that his use of the word phonological is an attempt to
remain agnostic over the nature of the encoding in vSTM, and does not rule out that
music can be processed by the phonological loop (Baddeley & Larsen, 2007).
However, if vSTM is phonological in this sense, then it is difficult to distinguish
vSTM and long auditory storage experimentally, and it is thus possible that some
effects ascribed to vSTM are actually the result of long auditory storage, or vice versa. It is commonly argued that, because of the phonological similarity effect (PSE), vSTM specifically retains phonological information (e.g., Baddeley, 2000; Gupta & McWhinney, 1997). The PSE is the finding that the presence of similar sounding words in a list impairs recall – for example, recall of the word cap in a word list is poorer if the word cape is also present in the list (Baddeley, 1968). Baddeley (2000) argues that the phonological loop, part of his conception of vSTM, is where the PSE occurs (see Section 4.4.1). It should be noted that this explanation of the PSE is currently controversial; D. Jones et al. (2004) argue that the PSE is an effect of auditory memory, whereas Baddeley and Larsen (2007) argue that the results reported by D. Jones et al. (2004) are due to a special case, which can be explained by their model as a result of vSTM. In any case, if memory for melodies involves vSTM, the same properties of vSTM that cause the phonological similarity effect should be present when melodies are being processed. If memory for melodies involves vSTM, then, insofar as melodies and word lists are equivalent, the equivalents of effects found in vSTM, such as the phonological similarity effect, should be found in memory for melodies.

4.3.2.1 The role of verbal short term memory in memory for melodies

There is too little empirical evidence to conclusively determine the relationship between memory for melodies and vSTM. Some neuropsychological studies find that deficits in melody processing are associated with deficits in working memory, whereas other studies find no association (see Section 3.3.3). This inconsistency in findings may be due to theoretical and empirical issues with the study of amusia (see Section 3.3), or due to the lack of a neuropsychological relationship. However, a small amount of research has attempted to test the relationship between memory for melodies and vSTM (e.g., Schendel and Palmer, 2007; Williamson et al., 2006). In the Williamson et al. (2006) experiment, participants without musical training serially recalled melodies of between four and seven notes in length, using only three pitches. Melodies were drawn onto paper by placing a cross in one of three boxes for each serial position. Using this paradigm, serial recall was more accurate if the pitch
intervals between the notes were larger (e.g., a melody using the notes C4, G4, & B4 was more accurately recalled than a melody using the notes C4, D4, & E4). Williamson et al. argued that this effect of pitch height was broadly equivalent to the PSE. However, their results may also be explained as the effects of the cognition of PIM. Participants may have made more errors in the smaller pitch interval condition because some pitch intervals are steps, whereas in the larger pitch interval condition, all pitch intervals are leaps. Leaps are considered to be pitch accents in M. R. Jones’s (1993) dynamic pattern structure hypothesis; if so, leaps would be more salient than steps. Nonetheless, whether this effect is because of the use of changes to PIM or whether it is because of a PSE, the effect is due to some form of auditory confusion. Although theories of working memory and theories of memory for melodies might postulate different explanations, deciding between these two possibilities is an open empirical question.

Schendel and Palmer (2007) tested the effect of articulatory suppression on a serial recognition task involving tone sequences. Participants with musical training either repeatedly said “the” or sung “la”, in a serial recognition task using either words or four note tone sequences. In the condition involving tone sequences, participants had to detect one or two semitone note alterations in tonal melodies in the key of C major, with either visual or auditory presentation (e.g., they heard the melody or read it from a score). Schendel and Palmer found that there was no difference between the effect of musical suppression and verbal suppression on the serial recognition of word lists or tone sequences; this may imply that the same mechanism is responsible for melodies and word lists. However, it is unclear from their paper whether the one or two semitone note alterations in their experiment altered contour, and it appears likely that the one or two semitone note alterations involved alterations to implied harmony though not major alterations to tonality; Schubert and Stevens (2006) suggest that alterations to implied harmony are salient to musicians. Additionally, Schendel and Palmer (2007) did not include any condition where the melodies were transposed with auditory presentation; this condition would have been informative about the respective influence of pitch memory and memory for melodies (or vSTM) in their findings. Although the research of both Williamson et al. (2006) and Schendel and Palmer (2007) suggest a possible link between memory for melodies and vSTM, their research does not yet conclusively demonstrate that memory for melodies is
equivalent to memory for lists of words. However, whatever the nature of the relationship between vSTM and memory for melodies, any model of memory for melodies must be able to explain the effect of articulatory suppression on musical stimuli in the experiment of Schendel and Palmer (2007), and must be able to explain the effect of pitch height reported by Williamson et al. (2006), insofar that those experiments are using melodies that must be memorised.

4.3.3 Long Term Memory Influences on Verbal Short Term Memory

Knowledge from LTM affects vSTM. Long term information is used to maximise the capacity of vSTM, and vSTM may use psycholinguistic information to repair decayed traces. This section will discuss those processes and their possible operation in memory for melodies.

4.3.3.1 Chunking

Although the capacity of STM appears to be three to five chunks of information (Cowan, 2000), people appear to have the ability to use LTM information to extend the amount of information by chunking. Cowan defines a chunk as “a collection of concepts that have strong associations to one another and much weaker associations to other chunks concurrently in use” (2000, p. 89). An individual chunk can be a phoneme (e.g., /w/), a word (made up of phonemes, e.g., well), or a phrase (made out of words, e.g., the Gough Whitlam quote, ‘Well may we say ‘God save the Queen’, because nothing will save the Governor General’), as long as it leads to an efficient encoding of information. Efficient chunking, Simon (1974) argues, uses long term memory information. For example, audiovisual recordings and written transcriptions of the Gough Whitlam quote above are familiar to Australians due to its association with important events in Australian history. Because of this familiarity, this phrase is easier to chunk than a less familiar phrase with a similar length in words or syllables. Simon (1974) argues, however, that recall of a well known phrase, considered as a chunk, is less accurate compared to the recall of a nonsense syllable considered as a chunk. Simon attributes this decrease in accuracy to the temporal capacity limit of
STM. Thus chunking appears to make STM more accurate via the association of concepts. However, current vSTM models do not often focus on how vSTM deals with syntactic and grammatical information, and so it is unclear in these models what mechanisms are responsible for chunking using syntax and grammar. A review by Caplan and Waters (1999) argues that neuropsychological and cognitive evidence suggests that the processing of sentences is the result of a mechanism separate from vSTM. People with limited vSTM capacity, according to Caplan and Waters (1999), do not appear to have an equivalent limited capacity to interpret sentences, and do not appear to have substantially more trouble with complex and ambiguous sentences like garden path sentences (e.g., *The experienced soldiers warned about the dangers before the midnight raid.*) than people with average vSTM capacity. However, it appears that people with limited vSTM capacity have only a limited capacity to manipulate information in a sentence beyond interpretation. Caplan and Waters (1999) therefore advocate that working memory models should include an extra component that is specialised for the processing of syntax in the interpretation of sentences. However, no major model of memory for word lists surveyed has thus far incorporated this suggestion. Regardless of this deficiency of many vSTM models, memory for melodies is likely to use syntactic information in information chunking, and thus a model explaining memory for melodies needs to account for chunking.

### 4.3.3.2 Psycholinguistic knowledge in verbal short term memory

Psycholinguistic and lexical information in LTM influences memory for word lists. In particular, a variety of effects based on phonological, phonemic, and lexical knowledge of the words used in word lists in typical STM tasks appear to influence serial recall. Firstly, there is an effect of lexicality; that is, memory span is larger for words than nonwords – for example, *rain* is better recalled than *yane* (Hulme, Maughan, & Brown, 1991). Secondly, there is an effect of word frequency; that is, memory span is larger for more commonly used words than less commonly used words – for example, *rain* is better recalled than *bane* (Roodenrys, Hulme, Alban, Ellis, & Brown, 1994). Thirdly, there is an effect of semantic knowledge; that is, memory span is larger for semantically linked lists than semantically unlinked lists –
for example, a list like ‘two, five, twelve, ten’ is better recalled than a list like ‘two, pie, Joan, feet’ (Wetherick, 1975). Finally, there is an effect of lexical neighbourhood size; that is, a word’s lexical neighbourhood size is determined by the amount of words that differ from it by one phoneme; wed has more lexical neighbours than turf. Memory span appears to be greater for words with more dense neighbourhoods than those with more sparse neighbourhoods (Byron, 2003; Roodenrys, Hulme, Lethbridge, Hinton, & Nimmo, 2002).

It has been argued that such effects are due to a redintegration process, where incomplete traces of words in STM are reassembled by a competitive queuing process on the basis of LTM information (Gathercole, Frankish, Pickering, & Peaker, 1999; Schweickert, 1993). For example, if required to remember the word fort, the temporal capacity limits of vSTM may lead to an incomplete trace like for? being retained. A redintegration process uses statistical lexical knowledge to reassemble the memory trace. As a result, it is more likely to mistakenly reassemble the word as fork, instead of fort, if fork is a more common word than fort, if other words in the list are also semantically associated with eating, and/or if fork has more lexical neighbours than fort. This argument is supported by evidence indicating that psycholinguistic LTM information plays a weaker role in serial recognition tasks than in serial recall tasks (Gathercole et al., 2001), as incomplete traces from the first presentation in a serial recognition task can simply be compared to the target presentation, without need of a redintegration process. However, where the target presentation is different from the first presentation, increases in the phonemic similarity of words in the lists cause increased error rates (Nimmo & Roodenrys, 2005). If memory for melodies is a function of vSTM, LTM knowledge, equivalent to lexical knowledge, should influence memory for melodies.

4.3.3.3 The role of long term memory information in memory for melodies

There are several experiments that appear to show that LTM knowledge about music has some effect on memory for melodies. Firstly, there is an equivalent of the lexicality effect. Dyson & Watkins (1984) found that the discrimination of melodies
that participants had been familiarised with was less reliant on melodic contour than the discrimination of unfamiliar melodies. Secondly, LTM knowledge of tonality influences the discrimination of melodies in a melody recognition task (Dowling, 1978, 1991). However, because of the differences in structure between music and speech, it is difficult to find exact comparisons between effects of LTM psycholinguistic information and possible LTM influences on memory for melodies. The rarity of unambiguous semantic meaning in music (Cross, 2003) makes it unlikely that an analogue of the role of semantic knowledge in vSTM will be found in memory for melodies. However, LTM psycholinguistic information, in general, may be broadly equivalent to those musical expectancies that are acquired through experience (Bharucha, 1994; Huron, 2006; L. Meyer, 1956; Narmour, 1989; Schellenberg, 1997). The term *musical expectancies* refers to LTM knowledge, held by both those with and without musical training, about the statistical likelihood of one pitch or temporal event following another. These expectancies appear to be important to the perception of music; for example, Schellenberg (1998) found that participants more often expected smaller pitch intervals and more often expected contour alterations. Huron (2006) argues that the successful manipulation of such expectancies by musicians and composers is equivalent to the successful manipulation of the affect of a listener. For example, research suggests that unexpected changes in a piece of music can reliably cause the experience of chills (Panksepp, 1995). As such, expectancies may be at least as important to music as psycholinguistic knowledge is to speech and language, and so musical expectancies should play a role in memory for melodies. However, again, what research there is on LTM influences on memory for melodies exists is focused on *what* information is used, as opposed to *how* this information is used; no available published research has investigated the possibility that redintegration-like processes are involved in memory for melodies.

Humans appear to use hierarchical information to chunk melodies, and as a result it may be impossible to calculate the basic capacity of memory for melodies. Lerdahl and Jackendoff (1983, 1984) and M. R. Jones (1993) suggest that knowledge of the hierarchical structure of the music, the syntax of the music, is used extensively in the chunking of melodies. Patel (1998, 2003) argues, based largely on evidence from neuropsychology and neuroimaging, that the short term processing of this syntax is shared with the short term processing of syntax in language, but that language and
music use substantially different LTM syntactic knowledge. In music, this hierarchical chunking process may be especially efficient, considering that the influence of what appears to be hierarchical knowledge about a piece of music leads to good memory for alterations to melodic contour even with large amounts of what would usually be considered interfering information between the familiarisation melody and the target (Dowling et al., 2002). However, Boltz and M. R. Jones (1986) have argued that the effects of hierarchical knowledge found in the discrimination of memory for melodies (e.g., M. R. Jones et al., 1982) are more convincingly explained in terms of dynamic accent structure (M. R. Jones, 1993), so it is unclear what effect that hierarchical information has on memory for melodies in contexts that use less LTM information. Caplan and Waters (1999) suggest that the neural processes devoted to syntax interpretation are separate to those devoted to verbal short term memory; if Patel (1998, 2003) is correct, and the STM processing of syntax of music is the result of the same module as the STM processing of the syntax of language, this suggests that the STM processing of musical syntax is separate to verbal short term memory. The extent of this separation is, however, still an open empirical question.

If memory for melodies uses hierarchical information extensively in the chunking of information in melodies, and if chunking in melodies works similarly to chunking in vSTM, it may be difficult to measure capacity limits in memory for melodies. Cowan (2000) argues that the measurement of chunking relies on two assumptions. The first assumption is that subjects are unable to group items into higher-order chunks because of experimental techniques like articulatory suppression, and the second assumption is that items in memory tasks are familiar units, which have no pre-existing associations between items that could lead to the encoding of multi-object groups. It appears impossible to ensure either of these assumptions is valid in musical stimuli, as the workings of musical expectancies (e.g., Huron, 2006) appears to ensure that pre-existing associations between notes in an unfamiliar melody are not only apparent but important and implicit in the emotionality of music, even in atonal melodies. Although research seems to suggest that articulatory suppression has some effect on the discrimination of melodies by adult listeners encultrated into the Western musical tradition (Schendel & Palmer, 2007), the hierarchical grouping of musical notes into higher-order chunks is implicit, automatic, and complex, and Schendel and Palmer (2007) used four-note melodies that are unlikely to need much
chunking in STM. It is an open empirical question as to whether this hierarchical chunking is suppressed by the use of articulatory suppression. Thus it is difficult to accurately determine capacity for musical information. This leads to difficulties in assessing whether capacity limits in vSTM and in memory for melodies are similar, a comparison that could potentially provide evidence about their similarity.

It is clear that LTM information has an effect on vSTM and most likely memory for melodies. However, there is relatively little evidence about what mechanisms may result in this effect in memory for melodies, as little research has looked into the role of musical expectancies in memory for melodies. This thesis will investigate the role of musical expectancies in memory for melodies. Nonetheless, any model of memory for melodies must be able to explain why familiar melodies are more accurately discriminated than unfamiliar melodies (e.g., Dowling & Fujitani, 1971; Dyson & Watkins, 1984), and why tonal melodies are more accurately discriminated than atonal melodies (Dowling, 1991).

4.3.4 Conclusions about Verbal Short Term Memory and Memory for Melodies

In summary, the tasks used in research into vSTM and in research into memory for melodies are similar. Additionally, there are effects found in vSTM research that are analogous to many of the effects found in memory for melodies research. Although there is little conclusive evidence that confirms whether or not memory for melodies is simply a function of vSTM, any model of memory for melodies must be able to explain several aspects of memory for melodies that have vSTM equivalents, such as the familiarity effect (e.g., Dyson & Watkins, 1984), the tonality effect (e.g., Dowling, 1991) and the effect of articulatory suppression on memory for melodies (Schendel & Palmer, 2007). Similarly, this review of the literature suggests that if memory for melodies is equivalent to vSTM, or resembles vSTM, then memory for melodies is likely to involve i) LTM knowledge about musical expectancies, ii) some mechanisms for chunking, and iii) capacity limits equivalent to those in vSTM.
4.4 Can Models of Verbal Short-Term Memory Explain Memory for Melodies?

If typical effects found in the vSTM literature have analogues in the memory for melodies literature, the ability of theories of vSTM to account for those effects in the memory for melodies literature should also be considered. There are numerous models of vSTM (c.f., Baddeley, 1997, 2000; Baddeley et al., 1998; Berz, 1995; G. Brown, Preece, & Hulme, 2000; Burgess & Hitch, 1999; Gupta & MacWhinney, 1997; Martin, Lesch, & Bartha, 1999; Nairne, 1990, 2002; Neath & Nairne, 1995; Ockelford, 2007; Page & Norris, 1995; Schweickert, 1993). Some models of vSTM are connectionist, based on computational modelling of the distribution of activation to layers of neuron-like units (Burgess & Hitch, 1999; Gupta & MacWhinney, 1997); some models of vSTM are modular, with dissociable modules serving different functions (Baddeley, 1997, 2000; Baddeley et al., 1998; Berz, 1995); some models are abstract and mathematical, being largely agnostic about cognitive structures and instead using mathematical formulae to predict effects in vSTM (Nairne, 1990, 2000; Neath & Nairne, 1995); finally some models are oscillatory, using oscillators to explain temporally-based phenomena regarding memory for word lists (e.g., Brown et al., 2000). However, despite this wide range of models, few of these models have attempted to account for memory for tonal information, let alone attempted to explicitly determine the relationship between memory for melodies and theories of vSTM.

As most models of vSTM do not discuss music, most memory for melodies research has avoided explicit reference to vSTM models (e.g., Dewitt & Crowder, 1986; Dowling, 1978, 1991; Dowling & Bartlett, 1981; Edworthy, 1985a; M. R. Jones et al., 1982, M. R. Jones & Ralston, 1991). Some researchers explain their findings in terms of theories of perception (e.g., Dyson & Watkins, 1984, who reference the visual information processing model of Kroll & Hershenson, 1980). Stevens and Latimer (1997) explain their results by reference to a single-layer connectionist model with inputs for each of the notes used in their atonal melodies; it should be noted that this connectionist model is narrow in its scope, only attempting to model the discrimination of monophonic atonal melodies. Dowling et al. (2002) explain
counterintuitively strong results of strong memory traces of melodies after some minutes of interfering tones by reference to TODAM, a model of human memory (e.g., Murdock, 2005), which interprets vSTM as a manifestation of LTM in a way broadly similar to Nairne’s model (see Section 4.4.2). This general agnosticism about vSTM theories (excluding the exceptions above) is likely due to limited evidence about the relationship of vSTM and memory for melodies.

However, although most memory for melodies research has avoided discussions of vSTM, it is necessary to assess both the actual and potential capability of theories of vSTM to account for memory for melodies, as the extent that vSTM can explain memory for melodies has implications for the evolutionary status of music. The models of Baddeley et al. (1998), Gupta and McWhinney (1997), and Nairne (1992), represent three kinds of vSTM models - modular models, connectionist models, and mathematical models, respectively. These models will be assessed for their ability to explain memory for melodies. It will be argued that none of these models are able to convincingly predict or explain findings from the memory for melodies literature without further revisions to incorporate melodic material.

4.4.1 A Modular Model of vSTM: The Phonological Loop

The phonological loop model (Baddeley, 1997, 2000; Baddeley & Hitch, 1974; Baddeley et al., 1998) is a modular model of verbal short term memory with two central mechanisms. A recent update of Baddeley’s model (Baddeley et al., 1998) is depicted in Figure 4.1. The first mechanism is the phonological short term memory, a limited store of verbal information. The second mechanism is the articulatory system, a subvocal rehearsal mechanism that, Baddeley argues, works something like a loop of tape and that can hold about two seconds of information. The articulatory system both refreshes the phonological store and encodes visual traces into phonological form. The phonological loop is a module in a broader model of short term memory, working memory, which also discusses visual short term memory and attentional and executive processes. In recent versions of the model (Baddeley, 2000; Baddeley et al., 1998), information from auditory analysis and speech perception is sent to phonological short term memory, whereas information from visual analysis and word
identification is sent to the articulatory system (e.g., humans subvocalise written words when they read; this subvocalisation is thought to convert visual information into phonological information). Baddeley additionally argues that there is interaction between phonological short term memory and phonological long term memory, thus explaining the various effect of word knowledge on verbal short term memory (see Section 4.3.3.2). A recent model by Baddeley (2000) has added a separate module, the episodic buffer, a modality independent store designed, firstly, to account for the ability of people to chunk information even when LTM is disrupted by articulatory suppression, and secondly, to explain the integration of information from different modalities; Baddeley (2000) suggests that the episodic buffer resembles conscious awareness.

![Diagram of the Baddeley et al. (1998) revision of the phonological loop model.](image)

*Figure 4.1. The Baddeley et al. (1998) revision of the phonological loop model.*

Although the model of Baddeley et al. (1998) can explain many effects of working memory (e.g., the PSE and the WLE), it has been criticised for its inability to explain how memory traces are temporally structured, as it has no mechanism for
remembering the temporal order of stimuli (Burgess & Hitch, 1999). This lack of a
temporal order mechanism is problematic for the ability of Baddeley’s model to
explain music, as the temporal structure of a melody is an important feature of that
melody, being the X axis to the Y axis of pitch; changing the order of notes in a
melody changes the identity of the melody. Additionally, several aspects of the model
are not immediately applicable to memory for melodies. As Baddeley et al. (1998)
argue that the phonological loop is specifically designed for language learning, the
model posits major roles for word identification processes, speech perception
processes, and phonological LTM processes; these processes appear to be of little use
to memory for melodies.

It is possible, in Baddeley’s (2000) model (see Figure 4.2), that music could be
processed by the episodic buffer, which is modality independent. However, the nature
of the episodic buffer remains unclear; Baddeley (2000) notes that it is unclear how to
empirically test the episodic buffer separately from vSTM or visual short term
memory; thus this feature of the model is not yet capable of explaining and predicting
memory for melodies. Finally, the focus on explaining results from an empirical
literature mainly concerned with lists of words and visual displays means that
Baddeley’s model has no mechanisms that could explain why melodic contour is
salient only in short term situations (Edworthy, 1985a), or why interval information is
more salient in tonal melodies (Dowling, 1991), to give two examples. It is plausible
that the working memory model can be modified so that it incorporates perceptual and
cognitive processes related to music (e.g., melodic expectancy) in a similar way to
those related to language (e.g., word recognition); in some ways the model described
in Chapter 5 does resemble a version of Baddeley’s model altered to incorporate
perceptual and cognitive processes related to music. However, it is currently unclear
how Baddeley’s working memory model would use these music-specific processes. In
conclusion, several aspects of Baddeley’s model do not apply to music, and the model
has difficulty explaining basic processes in memory for melodies.
4.4.2 A Connectionist Model of vSTM: Gupta and MacWhinney (1997)

Connectionist models of vSTM such as Gupta and MacWhinney’s (1997) model (see Figure 4.3) posit that different cognitive functions can be explained as the result of the interaction of groups of artificial neurons often organised into layers, which can be computationally modelled. The activation of neurons in these layers, and the interaction between neural activation in different layers, results in the emergence of behaviours such as correctly remembering a word or discriminating between melodies. Gupta and MacWhinney’s (1997) model can be illustrated by their account of the frequency effect. In this model, connections between the phoneme layer, which deals with individual phonemes, and the phonological chunk layer, which deals with word forms, become stronger as the frequency of the word increases. Errors where less common words (e.g., *shun*) are mistaken for more common words (e.g., *sun*) are, according to Gupta and MacWhinney (1997), because the phonemes in *shun* activate not only the phonological chunk layer representation of *shun*, but also other similar words such as *sun*, *fun*, and *gun*, to different degrees. In the case of *sun* and *shun*, the different word frequency may mean that the connection from the phonemes in *shun* to the phonological chunk *sun* is stronger overall than the connection between the
phonemes in \textit{shun} and the phonological chunk \textit{shun}. If there is more activation in the system for \textit{sun} than \textit{shun}, \textit{sun} may be recalled.

As can be seen in Figure 4.3, Gupta and MacWhinney’s model of verbal short term memory is like Baddeley’s model in that it features many layers that are specific to the perception and production of language, and that have limited applicability to music. As with Baddeley’s model, however, it is possible that the Gupta and MacWhinney model could incorporate musical information, in principle, with some modifications; for example, the phonological chunk layer (see Figure 4.3) may also be able to hold short melodic phrases. However, because the model is specifically designed to account for the processing of lists of linguistic information, it may be unable to account for the processing of melodies. For example, the model appears to be incapable of processing relational information; it has no mechanism for considering the syntactic relationships between words, but instead only considers the words as items on a list. In the discussion of chunking in the model, words are associated together as a chunk. Thus, there is no mechanism in the model that can analyse the relationship between musical notes. This causes major difficulties for this model’s ability to be adapted to melodic information, which is relational in nature.

In summary, as with the Baddeley et al. (1998) model, several aspects of the Gupta and MacWhinney model are specialised for processing linguistic information, and the model is therefore incapable of dealing with relational information, an essential aspect of melodies. Thus, the model needs further revision for it to be capable of explaining results from the memory for melodies literature.
4.4.3 Nairne’s Feature Model

The feature model posited by Nairne and associates (Nairne, 1990, 2002; Neath & Nairne, 1995) attempts to mathematically predict performance in vSTM tasks. According to Nairne, there are two mutually independent types of memory traces used in immediate serial recall settings. The first, *modality dependent features*, refers to the presentation modality and conditions of presentation – for example, the way the word *sun* sounds when you hear it as part of a list. The second, *modality independent features*, are the internally generated features of the item generated by the interaction of the stimuli with cognitive processes – for example, the concepts associated with the word *sun*. In Nairne’s feature model, the probability that a particular trace in secondary memory, $SM_i$, will be used as a recall response in primary memory, $PM_i$, (i.e., whether words are recalled) can be predicted by the following equation:
\[ P_s(SM_j|PM_i) = \frac{w_{ij}s(i,j)}{\sum_k w_{ik}s(i,k)} \]

where \( w_{ij} \) and \( w_{ik} \) are response-bias weights and \( s(i,j) \) and \( s(i,k) \) represent the similarity between the secondary memory and primary memory traces (Neath & Nairne, 1995). Neath and Nairne (1995) argue that the feature model is able to explain the WLE, the PSE, recency effects and the effects of articulatory suppression. That the feature model is modality-independent means that it is potentially more suitable for explaining effects found in the memory for melodies literature than the modality-dependent models of Gupta and McWhinney (1997) and Baddeley et al. (1998). However, there are a number of problems associated with using this model to deal with musical stimuli. This model has no mechanism for explaining how the correct temporal location of stimuli is retained, which, as discussed in Section 4.4.1, is particularly problematic for models that attempt to explain memory for musical stimuli. Another issue is that music is by nature largely modality-dependent. Although, in Western culture, there are high rates of literacy regarding written words, there are not similar high rates of literacy regarding musical notation. Thus, music is modality-dependent for those without musical training; as such, if Nairne’s model applies to melodies, musical training should have a significant effect on how musicians discriminate melodies compared to nonmusicians. Musicians highly proficient with musical notation, according to Nairne’s model, should be able to remember melodies more accurately because of their ability to translate melodies into a modality independent form. Whether musicians have better memory for melodies because they are able to use modality independent forms is an empirical question. However, it could be also be argued that the use of transposition in melody discrimination tasks means that the effects found in those tasks are modality-independent; participants must use a relational code to compare melodies under conditions of transposition, and a relational code must be to some extent modality-independent. If one considers LTM expectancy processes as modality independent features, where modality dependent features include, for example, contour, it may be possible for this model to explain effects such as the differential role of STM and LTM in regards to contour and tonality (e.g., Dowling, 1991); the Nairne model presumably predicts that modality independent features (e.g., tonality) will decay.
more slowly than traces of the modality dependent features (e.g., contour). However, if the use of transposition is equivalent to the forced use of modality independent features of melodies, Nairne’s theory will not be able to explain memory for melodies, as changes in tonality and melodic contour should be equally salient, as if the melody is transposed it appears to be modality independent. In summary, though the feature model has an advantage over other models of vSTM in that it is capable, in principle, of explaining memory for melodies, because it is designed to be modality-independent, it does not appear to be able to explain effects found in the memory for melodies literature.

4.4.4 Conclusions about the Capacity of Models of Verbal Short-Term Memory to Account for Memory for Melodies

Models of vSTM in their current form appear to be unable to account for memory for melodies. This inability to account for memory for melodies is because these models have been drafted largely to account for effects found in empirical research involving memory for word lists; such research strongly suggests that perceptual processes specifically to do with language, and LTM knowledge about language, plays a role in memory for word lists. Though, in principle, these models may be adapted to deal with musical stimuli, only the model of Nairne (1992, 2002) even claims to be able to explain effects found in the memory for melodies literature, insofar as Nairne’s model is an attempt to explain memory in general. However, Nairne’s model appears unable to explain the different salience of different musical features in different situations. Thus, the inability of vSTM theories to account for memory for melodies, and the lack of cognitive theories specifically devoted to memory for melodies, lead to the conclusion that a model specifically representing memory for melodies is necessary.
4.5 Can Current Models of Short-Term Memory for Musical Material Account for Memory For Melodies?

There are currently two models of short term memory that are specifically modelling short term memory for musical material – those of Berz (1995) and Ockelford (2007) – and one model of music processing (i.e., Peretz & Coltheart, 2003) which attempts to explain findings from what are essentially melody discrimination tasks (see Sections 3.3 and 3.4) in a more general framework than STM. It will be argued in Section 4.5 that neither model is capable of satisfactorily explaining results from the memory for melodies literature.

4.5.1 The Berz (1995) Model

The model of Berz (1995) attempts to explain memory for melodies as a function of vSTM. Berz’s model, which consists of the phonological loop (Baddeley, 1997; see Section 4.4.1) plus an added component that deals with musical stimuli, is underspecified. The model does not appear to specify if or how this component and other aspects of the phonological loop interact. Ockelford (2007, p. 6) therefore argues that the model of Berz “raises more questions than it answers”. This inability to answer questions about the relationship between music and vSTM, and its inability to make predictions about how the musical stimuli component and other parts of the phonological loops might interact, is unsurprising considering the scarcity of research that has explicitly attempted to find effects of vSTM using melodies as stimuli. Because of this scarcity of research, Berz has no evidence upon which to make strong hypotheses about the way vSTM processes musical stimuli, and thus his model cannot make specific predictions about how this added box processes musical stimuli. As such, Berz’s model is, at best, most informative about the challenges which must be overcome in putting together a theory of memory for melodies; it is not appropriate to base experimental work regarding memory for melodies on the model.
4.5.2 The Peretz and Coltheart (2003) Model of Music Processing

Although not a model of memory for melodies in the same sense as those of Berz (1995) or Ockelford (2007) – the model has no box corresponding to short term memory – the model of music processing by Peretz and Coltheart (2003) attempts to explain research using melody discrimination tasks (e.g., Peretz, 1990). Thus it must be considered as a model attempting to explain memory for melodies. The Peretz and Coltheart (2003) model is a modular model that attempts to explain effects found in the neuropsychological research of Peretz and colleagues (e.g., Peretz, 1990; Peretz & Kolinsky, 1993; Liégeois-Chauvel et al., 1998; see Sections 3.3 and 3.4). As such, the main rationale for constructing the Peretz and Coltheart (2003) model was that, where dissociations and double dissociations were found, it was likely that the reason for the dissociations was the presence of two separate submodules in the greater module of music processing. Thus, Peretz and Coltheart (2003) detail specific modules dedicated to contour analysis, interval analysis, tonal encoding, rhythm analysis and metre analysis, along with links between these modules and other cognitive functions like the phonological lexicon, emotional expression analysis and acoustic analysis (c.f., Figure 4.4).
Figure 4.4. The Peretz and Coltheart (2003) model of music processing. Dashed lines refer to the presence of modules, while the boxes inside refer to submodules.

The Peretz and Coltheart (2003) model is useful as a summary of the results of neuropsychological research on people with amusia, but it is prone to two major weaknesses. Firstly, the construction of the model was largely based on neuropsychological evidence. It has been argued that this approach is problematic, as neuropsychological evidence is best used as a way to test cognitive hypotheses, rather than a basis on which to construct theories (Bergeron, 2007; see Section 3.3.1.1 for a more detailed analysis). As most of the research that Peretz and Coltheart (2003) attempt to explain is research into people with amusia, it is possible that the aspects of the model are based on findings that are peculiar to people with amusia; people with amusia may compensate for deficiencies in ways that are misleading about music processing in normal brains. Secondly, because of the focus of the model on neuropsychological evidence the model appears to focus more on what aspects can be proven to be dissociated rather than focusing on the way things may be processed. As such, the model mentions little in the way of attentional or memory processes, and does not posit a submodule for a working memory process.
Secondly, a critical study of the evidence for dissociations and double dissociations using the principles of Dunn and Kirsner (1988, 2003) in the work of Peretz and colleagues suggests that the evidence is stronger in some areas of music processing than in others (see Section 3.3.2 for a critical analysis). In particular, the literature on acquired amusia shows strong evidence for a double dissociation between arrhythmia and amelodia, and a dissociation between rhythm processing and metre processing; however, evidence that metric deficits are possible without rhythmic deficits is weaker. Furthermore, the evidence regarding dissociations between contour and interval processing is weak and conflicted. Thus, some submodules in the Peretz and Coltheart (2003) model are better supported by the evidence than others. This may suggest that aspects of the model warrant revision.

Because the Peretz and Coltheart (2003) model is largely based on the finding of dissociations between different forms of processing, it is difficult for this model to explain findings from the literature on relational memory for melodies, using melody discrimination tasks. For example, the model posits no mechanism by which the effect of rhythmic information in a Garner interference task appears to affect pitch information in normal participants (Peretz and Kolinsky, 1993), or vice versa (Monahan et al., 1987; M. R. Jones et al., 1982). Similarly, although the model appears to posit that contour analysis occurs before interval analysis and tonal encoding (presumably influenced by the findings from ERP studies; see Trainor et al., 1999, and Section 3.4.2) it is difficult for the model to explain the relative difference in the salience of tonality and interval compared to contour in more short term situations compared to more long term situations, as the model does not posit an influence of the musical lexicon on tonal or interval analysis.

As such, the Peretz and Coltheart (2003) model is best thought of as a useful index of the dissociations that have been found between the processing of different musical features. However, it does not appear to be appropriate to use the theory to test the relational memory for melodies, as the model may be too specific to neuropsychological research to be able to explain findings from the cognitive psychology literature.
4.5.3 The Ockelford (2007) model

As can be seen in Figure 4.5, Ockelford (2007) is, like Berz (1995) a model based largely on Baddeley’s (1997) model of working memory; Ockelford (2007) indeed outlines an aim to explore and develop Berz’s (1995) model. Ockelford proposes that a submodule of working memory devoted to music is comprised of a “music executive” and “bundles” of LTM and STM information regarding music. By using the term “bundles”, Ockelford (2007) attempts to emphasise that the information in the bundles are dynamic and evolving rather than fixed strata of memory traces. The model suggests that the musical submodule of working memory is completely independent of the phonological loop, Baddeley’s (1997) term for phonological short term memory.

![Diagram of the Ockelford (2007) model of working memory for music.](image)

*Figure 4.5. The Ockelford (2007) model of working memory for music.*
Ockelford bases his model on a study of a musical savant and admits that the savant may not be representative of the general population. In drafting his model, Ockelford (2007) draws upon data from a qualitative experiment involving Derek Paravicini, a musical savant with severe learning difficulties. Ockelford takes this approach in preference to what he terms metamusical approaches (e.g., melody discrimination tasks) because he believes that zygonic note relationships are more important in complex musical material rather than simple melodies. Ockelford uses the term zygon to refer to relationships between note relationships; for example, the relationship between a rise in the melodic contour of a melody and a fall in the melodic contour of a melody is a zygonic relationship. In Ockelford’s (2007) experiment, Paravicini was asked to listen to a piece specially composed by Ockelford entitled “Chromatic Blues” and then to play the piece on a piano as best as he could; Paravicini was familiar with and capable of this kind of task. Ockelford (2007) has used Paravicini as a test study because Paravicini’s severe learning difficulties presumably suggests that there was major damage to his short term memory and central executive processing; thus, Ockelford (2007) argues, anything that Paravicini is still able to do after this damage must be the result of some module separate to verbal working memory or central executive processing. However, Paravicini’s abilities do not necessarily indicate that music cognition and perception in normal people is due to a separate cognitive module. As argued in Section 3.3.1.3, in regards to a specific cognitive ability, congenital neurological disorders are uninformative about normal cognitive processing, as the neurological differences are likely to be systemic rather than specific (Karmiloff-Smith et al., 2003). Although Paravicini’s condition was not a congenital condition, it was caused by oxygen deprivation during a premature birth, which led to pervasive brain damage before much brain development had taken place. Ockelford (2007) argues that there is no evidence of a structural difference between Paravicini’s cognitive architecture for music and those of normal people, as both Paravicini and other controls show the integration of short term and long term information, and chunking according to underlying structure. However, Paravicini is blind because of the same oxygen deprivation, and it may be likely, then, that Paravicini has been able to use areas of the visual cortex in the cognition and production of music, and though the general response is similar, Paravicini’s increased ability compared to the general population may be served by different
neural and cognitive mechanisms. Thus the arguments of Karmiloff-Smith et al. (2003) apply to Paravicini; it may be that his brain development after this brain damage was significantly different to the brain development of people in the general population, and that his responses to Ockelford’s (2007) task are unrepresentative of working memory for music in normal participants. That Ockelford separates the musical executive in his model from the central executive, and that he separates the short term musical bundle from the phonological loop, is based on the logic that Paravicini has little verbal working memory ability, but much musical ability, and thus musical ability must rely on different neural correlates to the ability to remember lists of words. However, because of the problems in generalising from Paravicini to the general population, this may not necessarily be the case.

Ockelford (2002, 2007) argues that all aspects of music are processed by a general relational processor that processes both relationships between notes, and relationships between note relationships (‘zygons’). Ockelford argues that this relatively simple framework can account for the way that musical expectancies affect humans. For example, in analysing Paravicini’s recalling of “Chromatic Blues”, Ockelford points to Paravicini retaining the melodic contour and rhythm of the opening phrase, and reconstituting them later in the piece, as an example of zygonic relationships. Ockelford (2007) claims that zygonic relationships are evident in perceptual processing effects such as the continuity illusion (Bregman, 1990) and in experiments testing musical expectations (e.g., DeWitt & Samuel, 1990); presumably Ockelford infers that both short term memory and long term memory use zygonic relationships in the memory for music. If this presumption is accurate, Ockelford (2007) is able to explain the many instances where LTM information affects memory for melodies. However, it appears that Ockelford’s model has no mechanisms that could explain why melodic contour is salient only in short term situations in comparison to interval information (Edworthy, 1985a).

Ockelford (2007) does, however, give some useful criteria for a successful model of working memory for music. Ockelford argues that, as humans hear music, they must be able to, firstly, “process incoming perceptual input, constantly searching for the repetition…that underpins musical structure and permits parsimonious encoding and ‘chunking’” (p. 29). Secondly, humans must be able to “prioritise what is sent to the
short term memory bundle, according to salience, reinforcement and other factors” (p. 29). Thirdly, humans must be able to “tag’ elements in a manner that shows how they were related (to facilitate future retrieval)” (p. 29). Fourthly, humans must be able to “send encoded fragments and features to long term memory to locate potential matches” (p. 29). Finally, humans must be able to “receive the potential matches from long term memory and to process these in parallel with incoming perceptual input to inform the listening process” (p. 29). The model detailed in Chapter 5 will fulfil these criteria.

4.6 Conclusion

It has been suggested that the cognition of melodic contour is an evolutionary adaptation (e.g., Cordes, 2003), and it is argued in this thesis that the cognition of melodic contour does not operate separately to other features of melody such as rhythm, but is instead part of memory for melodies. Determining the nature of the relationship between vSTM and memory for melodies is thus important in determining whether it is likely that the cognition of melodic contour is an evolutionary adaptation. Chapter 4 has argued that a comprehensive model of memory for melodies is necessary to more accurately determine the similarities and differences between vSTM and memory for melodies. Additionally, in areas equivalent to aspects of vSTM, any model of memory for melodies must be able to explain a) the relational nature of memory for melodies; b) the role of syntax in melodies; c) how pitch memory is used by memory for melodies; d) how articulatory suppression effects (Schendel & Palmer, 2007) and auditory similarity effects (Williamson et al., 2006) operate in memory for melodies; e) how the discrimination of familiar melodies is more accurate than the discrimination of unfamiliar melodies; f) how the discrimination of tonal melodies is more accurate than the discrimination of atonal melodies; g) how changes to tonality are more salient in longer melodies and melodies heard less recently; and h) how changes to melodic contour are more salient in shorter melodies and melodies heard more recently. Chapter 5 will introduce a model of memory for melodies that will attempt to explain these aspects of memory for melodies.
CHAPTER 5

The Components of a Model of Relational Memory for Melodies
5.1 Overview of the Model of Relational Memory for Melodies

In drafting a model of the cognitive function of relational memory for melodies, it is important to indicate what this model is expected to achieve. It is intended that this model becomes a falsifiable and empirically useful theoretical framework for explaining results in the field of short term memory for monophonic melodies. The criterion of falsifiability, that a model could potentially be proved wrong by empirical results (Popper, 1959/2002), is a widely held principle behind the development of psychological theories. Theories that cannot be proved wrong are thought to be unscientific; in contrast, theories that do not get proved wrong are considered good theories. In practice, however, Leahey (2004) notes falsified theories are rarely discarded, because the validity of the falsifying data can be attacked by the proponents of the theory, who may also argue that a bad theory is better than no theory at all, as it at least makes testable predictions. This model is intended to be falsifiable and thus make testable predictions. However, the model is based on incomplete and sometimes contradictory evidence (see Chapter 3), and as such may be superseded as more knowledge becomes available; as such this model is, at worst, intended to stimulate empirical and theoretical research that would inform future models. This model is a hybrid cognitive/connectionist model; although the model is not computationally realised, but is instead a standard box-and-arrows cognitive model, it draws on connectionist theories (e.g., Tillmann, Bigand, & Bharucha, 2000), as connectionist theories can often parsimoniously explain the workings of sections of cognitive models without invoking homunculi (e.g., Baddeley et al., 1998). It is not intended purely as a model of findings from the performance of normal participants in a melody discrimination task, but should be informed by a wider variety of research paradigms, such as neuropsychological studies of people with amusia, neuroimaging studies, melody recall tasks, priming tasks, and Garner interference tasks. Insofar as neural structure reflects neural function, predictions of this model should be reflected in findings from cognitive neuropsychology and neuroimaging studies, where the constraints of those methods permit accurate tests of this model.
This model of relational memory for melodies specifically examines the processes involved in adult memory for monophonic melodies in short term contexts. Processing, in this model, specifically refers to the manipulation and reworking of information. The model of relational memory for melodies posits that memory for melodies processes auditory stimuli in similar ways to vSTM, except for differences based on important differences between word lists and melodies. Thus, the model broadly resembles the phonological loop posited by Baddeley et al. (1998) except that the psycholinguistic processes posited by Baddeley are replaced by *psychomusical* processes dealing with musical expectancy (Huron, 2006; Tillmann, Bigand, & Bharucha, 2000) and dynamic accent structure (M. R. Jones, 1993; Morris, 1993). In summary, as seen in Figure 5.1, in this model there is a short term store of limited informational capacity, Short-Term Memory for melodies (STMm). This short term store, in this model, receives temporally ordered information that has been assembled using a relational code, with the dynamic accent structure marked as such, by the relational coding mechanism (RCM). Information, in this relational code, is lost as a result of decay or interference, and is reconstituted by a redintegration process using LTM schematic and veridical musical expectancies and memory traces from pitch memory. However, in situations where melodies are transposed, the system is unable to compare the relational form with memory traces in absolute pitch memory (in Figure 5.1 this comparison process is represented by the dotted line). While these are not depicted in the model or discussed at length, it is expected that the model of relational memory for melodies interacts with executive processes like the coordination of attention, decision making and information retrieval.
Figure 5.1. A model of relational memory for melodies. The dotted connecting line between absolute pitch memory and the redintegration process represents that the link is only available when there has not been transposition within melody pairs. The dashed square within which there is relational coding of pitch and temporal information, which is then integrated, represents that these three boxes are integrated as part of the relational coding mechanism.

5.2 Absolute Pitch Memory

The absolute pitch memory component of this model is considered to be analogous to Cowan’s (1984) concept of long auditory storage, or Deutsch’s (1975) concept of pitch memory (see Sections 4.3.1 and 4.3.1.1). Information in this store – whether pitch or timbre or duration – is not a literal representation of sensory information, but is influenced by perceptual and attentional mechanisms. Absolute pitch memory is considered to be a rapidly decaying source of accurate temporally ordered acoustic information. Musical stimuli, including both familiar and unfamiliar melodies, are automatically processed by absolute pitch memory in certain ways; for example, streams of sound are organised according to Gestalt principles such as similarity, continuation, figure/ground and so forth (e.g., Bregman, 1990; Dowling, 1973).
Melodic information in absolute pitch memory is used by the system in two different ways. Firstly, information from absolute pitch memory is sent to the RCM (see Section 5.3). Secondly, the redintegration process compares the highly processed relational form of melody in Short Term Memory for Melodies (STMm) with the decaying absolute pitch memory trace. As information in absolute pitch memory is rapidly lost, especially with interference from other tones, this comparison with absolute pitch memory accounts for the relatively greater accuracy in detecting interval information at short time intervals (Croonen & Kop, 1989), and the increased accuracy in detecting interval information in untransposed melodies (Dowling & Fujitani, 1971; Peretz, 1990) in melody discrimination tasks. It is proposed in this model that durational information in STMm is compared to durational information in absolute pitch memory in similar ways; that is, it is possible for information from absolute pitch memory to be retained in STMm if transposition does not occur. In this model, the use of key transposition within melody pairs in a melody discrimination task is thought to prevent the comparison of relational pitch information in the STMm with absolute pitch information in absolute pitch memory. Similarly, in this model, the use of transposition in tempo between melodies in a melody pair in a trial in a melody discrimination task is thought to prevent the comparison of temporal information in a relational pitch code in the STMm with temporal information in absolute pitch memory.

5.2.1 Predictions About Absolute Pitch Memory to be Investigated

A thorough investigation of absolute pitch memory is beyond the scope of the present study. However, because our current focus is on investigating the relational coding mechanism (see Section 5.3), it is necessary to control for absolute pitch memory when participants discriminate between melodies. For this reason, the experiments to be reported alter the absolute acoustic information in the comparison melody, compared to the standard melody, while leaving the relational information intact. This is achieved in Experiments 1a, 1b, 2, 5a, and 5b by transposing melodies in pitch, and is achieved in Experiments 4, 5a, and 5b by transposing melodies in tempo. Thus, in
the experiments reported in this thesis, absolute pitch memory will not be a reliable guide to discriminating between melodies.

However, in real-world situations, it is clear that absolute pitch memory plays a role in memory for music – people generally spontaneously sing “Happy Birthday” in the same key, for example. Experimental evidence suggests that long term memory for absolute pitch of television themes is more accurate than that expected by chance even in non-musician listeners (Schellenberg & Trehub, 2003), and melodies with transposition within-pairs are not remembered as accurately as melodies without transposition within-pairs (Peretz, 1990). Thus, it is clear that absolute pitch memory is likely to play a role in memory for melodies. Its interaction with other parts of the relational model of memory for melodies should be investigated more fully in future.

5.3 Relational Coding Mechanism

Ockelford argues that humans must have some ability to “process incoming perceptual input, constantly searching for the repetition…that underpins musical structure and permits parsimonious encoding and chunking…to prioritise what is sent to the short term memory bundle, according to salience, reinforcement and other factors… [and] to “tag” elements in a manner that shows how they were related” (2007, p. 29). The relational coding mechanism (RCM) in this model, which encodes the melody in a relational form, attempts to explain this ability. The use of the term relational in this model indicates that the form of information encoded by RCM is to do with the relationship between musical events, rather than the categorising of musical events. Many, if not most, musical attributes – for example, harmony, pitch intervals, rhythm, and metre – are relational in nature, in that they have to do with the relationship between notes rather than their absolute values. Indeed, some theories of music cognition focus exclusively on relationships between notes and relationships between abstract higher order events based on note relationships (e.g., Ockelford, 2002). To give a few examples: a melodic contour rises if the second note is higher than the first; an F# is dissonant in relationship to the key of C major but consonant in relation to the key of C# major; a syncopated note is only syncopated in relationship to an established metre, and the dynamics of a piece of music are established by, for
example, the relationship of louder notes to softer notes. The relational coding of melodies is likely to be necessary for music to be efficiently processed by higher order cognitive mechanisms.

In the model of relational memory for melodies, short term memory for melodies is considered to have the capacity to deal with between 3 to 5 chunks of information (c.f., Cowan, 2000). Because of this capacity limitation, RCM is not only required to encode melodic information in a relational form but is also required to encode melodies in such a way that those aspects of a melody considered most important to the structure of the melody are less likely to be forgotten than those aspects of a melody considered less important. Considering that there appears to be strong evidence for a dissociation between the processing of pitch information in STM tasks and the processing of rhythmic information in STM tasks (Peretz & Kolinsky, 1993), it is likely that pitch accents and durational accents are encoded separately, and later combined, which suggests that relational encoding in the REM mechanism may be subdivided into the relational encoding of pitch (Relational Pitch Coding [RPC], see Section 5.3.1) and the relational encoding of duration (the Relational Duration Encoder [RTC], see Section 5.3.2).

5.3.1 Predictions Derived from The Relational Coding Mechanism

The experiments to be reported have been designed to investigate the hypothesis that there is a perceptual process like the RCM which is involved in memory for melodies. Firstly, the use of transposition within-pairs in the experiments to be reported requires that participants cannot use absolute pitch memory to discriminate between melodies. In these experiments, if participants can – to any extent – discriminate between melodies, it demonstrates that participants have, at some level, encoded acoustic information in a relational way. Thus, any result reported here that suggests that participants can discriminate between melodies where there is transposition within pairs will lend support to the hypothesis that there is a perceptual process like the RCM which is involved in memory for melodies.
As to the specific structure of the RCM postulated here, previous research has found that a) there is a dissociation between the processing of pitch and the processing of rhythm in STM tasks (Peretz & Kolinsky, 1993) and b) there must be a process which integrates these separate musical properties into a coherent whole (J. Davies, 1979). The RCM therefore must be divided into at least three parts (Relational Pitch Coding, Relational Temporal Coding and Pitch/Time Integration; see Sections 5.3.2 to 5.3.4). Predictions about those specific parts of the model which are tested in this thesis are dealt with in sections 5.3.2.1, 5.3.3.1 and 5.3.4.1.

5.3.2 Relational Pitch Coding (RPC)

Relational pitch coding encodes melodies so that alterations to melodic contour and alterations to PIM are accentuated, and thus are less likely to decay than other parts of the melody. In the model, RPC codes relationships between pitch events, in such a way that temporally ordered changes in pitch direction (i.e., a melody going up where it was going down), and perhaps alterations to PIM (i.e., a pitch interval of a leap following several steps) are marked as important. Pitch accents (e.g., contour alterations) are salient to listeners both in short isochronous monophonic melodies under conditions of transposition (Dowling, 1978), and in more naturalistic stimuli (Peretz, 1990). That melodic contour is more salient in situations which encourage the use of short term memory (e.g., Edworthy, 1985a) is explained by, firstly, information in STM being encoded in such a way that melodic contour is important, and secondly by the way that schematic expectancy processes deal with contour (see Section 5.5). It is, however, unclear from the literature (e.g., Peretz, 1990; Stevens & Latimer, 1992) whether alterations to PIM are likely to be processed by this part of the model, as the dynamic accent structure hypothesis of M. R. Jones (1993) suggests (see Section 3.2.4), or if PIM is processed by LTM processes, or both; experiments testing PIM have not used transposed melodies, and have not deliberately varied melody length or ISI to determine the role of LTM information in the process. Experiments in this thesis will directly test the hypothesis that PIM is processed by the dynamic accent structure under conditions of transposition (see Chapters 6, 7, and 10); this hypothesis would predict that the processing of PIM will be similar to the processing of melodic contour. Under this hypothesis, PIM, like melodic contour, should be comparatively
more salient to participants in shorter melodies, in pairs of melodies with shorter ISIs, in melodies that are atonal, and in melodies that are familiar.

5.3.2.1 Predictions about Relational Pitch Coding

Experiments 1a, 1b, 2, 5a, and 5b have been designed to investigate hypotheses derived from this part of the Relational Coding Mechanism. Specifically, these experiments investigate the hypothesis that alterations to the dynamic pitch structure of the melody (e.g., changes to contour or PIM) will be salient to participants where there is pitch transposition within melody pairs. If such alterations are more salient to participants in shorter-term situations compared to longer-term situations (e.g., in shorter melodies compared to longer melodies, a variable used throughout these experiments), hypotheses suggested in this model, such as that the processing of dynamic pitch structure is relational, would be supported.

5.3.3 Relational Time Coding (RTC)

A relational time coding (RTC) mechanism is hypothesized to detect temporal accents. In the model of relational memory for melodies, RTC is a perceptual processor that accentuates pauses and long notes in the melody so that they are less likely to be forgotten than rhythmically unaccented (unimportant) notes (c.f., M. R. Jones, 1993) in a similar manner to how RPC processes pitch accents. That a model of memory for melodies needs to be able to account for the role of rhythmic information is suggested by the research of Peretz (1990), Boltz & M. R. Jones (1986), M. R. Jones & Ralston (1991), and Stevens and Latimer (1997), who all reported that durational information was salient in melody discrimination tasks.

However, it should be noted that there is no published research using melody discrimination tasks wherein melodies have been transposed in tempo, and that there is no widely available published research which has investigated the role of metre and pulse. Thus, it is difficult to determine the relationship between RTC, absolute pitch memory, and other general time perception processes (see Section 8.1). Additionally,
because of the lack of research on metre and pulse, it is difficult to determine whether RTC only discriminates between long and short notes or whether it takes into consideration higher-level temporal relationships between notes such as metre. Experiments 3, 4, 5a, and 5b, reported here, have been designed to address these questions in order to inform this model.

5.3.3.1 Predictions about Relational Temporal Coding

Experiments 3, 4, 5a, and 5b have been designed to investigate hypotheses derived from the Relational Temporal Coding part of the model. If alterations to the dynamic temporal structure of the melodies (e.g., changes to relative note length) are salient to participants where there is tempo transposition within melody pairs, then some form of Relational Temporal Coding mechanism must exist. In order to control for the possibility that it might have been deviation from the temporal grid rather than note length which is more salient, there were also other stimuli with smaller changes to relative note length which had larger deviation from the temporal grid; if such stimuli are more salient than stimuli with greater change to relative note length it would falsify the hypothesis in the model that the basis of relational perceptual processing in melodies is dynamic temporal structure. If such alterations are more salient to participants in shorter-term situations compared to longer-term situations (e.g., in shorter melodies compared to longer melodies, a variable used throughout these experiments), hypotheses derived from this model, such as that the processing of dynamic temporal structure is relational, would be supported.

5.3.4 Pitch/Duration Integration (PDI)

The separate relational encoding of pitch and duration must be integrated with each other before they enter the short term memory store (e.g., Peretz & Kolinsky, 1993), as memory for a melody appears to be memory for an integrated whole (J. Davies, 1979). Thus, it appears necessary to postulate a process where relationally coded information about pitch and about time are recombined. However, little research has focused on the integration of pitch and duration in memory for melodies (though, see M. R. Jones & Ralston, 1991), and none of this research attempted to determine the
principles under which separate encodings were integrated in a relational representation in short term memory. Thus it is unclear from experimental research how the relational encoding of pitch and duration are integrated, but clear that they must be integrated. However, in the model of memory for melodies, PDI is also responsible for the chunking of melodies, and it therefore is likely to process melodies using LTM information about the syntactic structure of music to recombine information from RTC and RPC (see Section 4.3.3.3; Lerdahl & Jackendoff, 1983; Patel, 2003).

5.3.4.1 Predictions about Pitch Duration Integration

Experiments 5a and 5b use a variant on a melody discrimination task, a Garner interference task, to test hypotheses derived from the Pitch Duration Integration part of the model. In Garner interference tasks, participants who have been instructed to ignore changes to one aspect of a stimulus, and attend to changes to a second aspect of a stimulus, are often unable to ignore the changes to the stimulus they were asked to ignore. Findings such as these have been used in previous research (e.g., Peretz & Kolinsky, 1993) to infer the existence of shared or separate processing of stimuli by modules or neural structures. Thus, if pitch and temporal information in memory for melodies is subject to a Garner interference effect, when participants are required to encode relationally, it will suggest that there must be a process which integrates pitch and temporal information before it is sent to the short-term store. Thus, Experiments 5a and 5b directly test the hypothesis that there is a process which (automatically) integrates pitch and temporal information.

5.4 Short Term Memory for Melodies (STMm) and Redintegration

It is proposed that information from RCM is then sent to the short term memory for melodies (STMm). STMm is identical to vSTM, and its form resembles Baddeley’s concept of the phonological loop (see Section 4.4.1). This assumption predicts that STMm has a limited informational capacity of between 3 and 5 chunks of information (Cowan, 2000), and which is subject to decay or interference, though the nature of
melodic stimuli is such that it may be that it cannot be accurately determined whether this capacity limit is true of musical stimuli (see Section 4.3.3.3). Additionally, STMm is considered as a form of working memory, capable of manipulating and structuring traces in memory, where it is appropriate. In a melody discrimination task, the memory system has to simultaneously hold information from the first melody and information from the second melody, so that relational information from the first melody can be compared with relational information from the second melody. This requires that the information be capable of being stored in a form suitable for manipulation. As such, information in STMm interacts with executive processes involving attention, decision making, information binding and inhibition.

Additionally, this store is refreshed by a redintegration process, which reassembles decaying traces in STMm. The purpose of the redintegration process is to reassemble melodic information that has been lost in STMm through decay or interference. In order to do this, schematic and veridical expectancies are used to guess what the missing information in the melody is likely to have been and replace the missing information. For example, if a melody had the tone sequence C4 D4 E4 F4 G4, and information about the fourth note, F, was lost in STMm, information in schematic expectancy processes regarding the note F are more activated than information regarding other notes; similarly, if the participant is already familiar with a melody with the tone sequence C4 D4 E4 D4 G4, information in veridical expectancy processes about the fourth note in the sequence leads to greater activation of the note D4. The redintegration process uses this information, along with its degree of similarity with the acoustic information in pitch memory if the melody pair is untransposed, to reassemble the memory trace in STMm. The presence of a redintegration process explains the increase in the salience of information corresponding to LTM knowledge (e.g., tonality) where the capacity limits of STMm are stretched.

5.4.1 Predictions About the STM store and Redintegration Process Tested in this Thesis
The present investigation does not focus on the STM store or the redintegration process. Insofar as Experiments 1b and 2 have been designed to investigate the role of LTM processes, they are testing the hypothesis that there has to be some process which integrates LTM information into STM representations. Equally, all experiments reported here, insofar that they assume that participants can hold a trace of a standard melody in STM with which to compare the comparison melody, assume that there is some form of STM store. However, these experiments are not designed to test predictions about whether redintegration processes or other processes are the best way to explain the integration of LTM information into STM representations. Similarly, the experiments to be reported are not intended to confirm or falsify hypotheses about the nature of the STM store. However, other experimental research (e.g., Schendel & Palmer, 2007; Williamson, Baddeley, & Hitch, 2006) has begun to address some of these issues.

5.5 Schematic Expectancies

As elaborated in Section 5.4, information about schematic expectancies in music is used by a redintegration process to reassemble decayed memory traces. Schematic expectancies are expectancies about a piece of music based on knowledge of music in general. These musical expectancy processes have identified statistical regularities in the music the listener has been exposed to over their lifetime (Huron, 2006). If the music that the listener has been exposed to is Western tonal music, then their musical expectancy processes will reflect the characteristics of Western tonal music - for example, that melodies typically end on the tonic (Huron, 2006). Several aspects of musical expectancy are directly relevant to memory for melodies. Firstly, in regards to pitch, tonality information and pitch interval information are used to reconstitute melodies. Secondly, in regards to duration, metric information is used to reconstitute melodies. It is possible that other features of music, such as timbre, are also processed by schematic expectancies, but there is little research on the role of timbre in memory for melodies, and therefore its role in this model is speculative at this stage.

The model assumes that the tonality of a melody is identified by a musical expectancy process similar to one described by Huron (2006), or to that described by Tillmann,
Bharucha, and Bigand (2000), who posit that the learning of tonality is due to a neural mechanism resembling a self-organising map (Kohonen, 1995). In the Tillmann et al. (2000) model, information from basic auditory processes activates a layer representing different pitches, which then activates a layer representing different tonalities; the tonality most activated by this process is used by the redintegration process to reassemble melodies. In monophonic melodies like those used in most melody discrimination tasks (though see Stevens & Latimer, 1992, who used polyphonic melodies), schematic expectancies use pitch interval information from pitch memory to detect tonality; pitches on accented notes and repeated pitches lead to stronger activation. Stronger activation of one tonality leads to higher likelihood that the redintegration process will be able to accurately reassemble a melody, as a stronger tonality restricts the amount of likely notes. That the activation of a particular tonality is a fundamental process to memory for melodies is suggested by Dowling (1991), who found that the presence of atonality in melodies made melodic contour more salient and interval information less salient. This suggests that the assumption of a particular tonality greatly aids activation of pitch interval expectancies.

After a tonality is assumed, schematic expectancies then calculate the expectancy of the pitch intervals in the melody. Schellenberg (1997) suggests that, in note-to-note melodic expectation, leaps in a melody are more unexpected than steps in a melody. Secondly, Schellenberg (1997) argues that a continuation of direction is more unexpected than a change in direction. Thus, it should be noted that, in the model, this means that melodic contour (e.g., changes in direction) is salient to RCM, but not salient to schematic expectancies. Thus, melodic contour is more salient in situations that encourage the use of STM or situations that discourage the use of LTM (e.g., Dowling, 1978, 1991; Dowling & Bartlett, 1981; Dyson & Watkins, 1984; Edworthy, 1983, 1985a, 1985b) In contrast, in this model, it is unclear based on empirical research whether PIM is salient to the relational coding mechanism or schematic expectancies. If PIM is salient to schematic expectancies, the prediction made by this model, therefore, is that, as schematic expectancies are a LTM process, PIM will be more salient than melodic contour in experimental paradigms that encourage the use of LTM information. This prediction will be empirically tested in Experiments 1a, 1b, and 2 (c.f., Section 5.6.1).
5.6 Veridical Expectancies

Veridical expectancies in this model access a lexicon of temporally ordered and accurate representations of familiar melodies, which are relational in the sense that transposition in tempo or key is irrelevant to the activation of this representation with various forms of the melody (e.g., “Happy Birthday” may be sung at different tempi, but – within a certain range of tempi – can clearly be recognised as “Happy Birthday”). Veridical expectancies are representations of melodies in a relational, abstract form, and the accuracy of the information in veridical expectancies is increased as the number of presentations of an item increases. If a melody is familiar, memory for melodies can use veridical expectancies in addition to schematic expectancies in order to accurately re-integrate melodies. This added capacity may explain why performance in melody discrimination tasks using familiar melodies is much higher than performance in melody discrimination tasks using unfamiliar melodies (e.g., Dowling & Fujitani, 1971). Dyson and Watkins (1984) find an improvement in recognition of unfamiliar melodies after a familiarisation period than after no familiarisation period, suggesting that there are veridical expectancies not only for well-known melodies such as “Mary Had A Little Lamb”, but also veridical expectancies for any melodies that have been heard, including any comparatively unfamiliar melodies that have been recently heard in a melody discrimination task. Thus, the model being developed here predicts that performance on a melody discrimination task should be less accurate where the veridical expectancies for a melody differs slightly from a presented melody, as the veridical expectancies for a melody get confused with the melody that was actually presented. This prediction will be empirically tested in Experiments 1a, 1b, and 2 (c.f., Section 5.6.1).

5.6.1 Predictions about Schematic and Veridical expectancies

Experiments 1a, 1b, and 2 specifically test predictions about the role of schematic and veridical expectancies made by the model under development. In particular, the model assumes that schematic and veridical expectancies are used to refresh degraded traces
in STM; the model thus predicts that, the more degraded the memory trace, the more likely that the discrimination of melodies is influenced by LTM expectancies. As longer melodies require more chunking than shorter melodies, and are thus more likely to be degraded, the model predicts that more expectable melodies – those with changes to PIM – are more likely to be remembered than less expectable melodies – those with changes to contour – in long melodies. Experiment 1b specifically tests the hypothesis that expectancies influence the discrimination of melodies by preventing participants from using expectancies to accurately discriminate between melodies. Experiment 2 specifically tests the hypothesis that veridical expectancies influence the discrimination of melodies, by preventing participants from using veridical expectancies to accurately discriminate between melodies.

### 5.7 Examples of How the Model May Work

A melody used in some experiments in this thesis will be used to illustrate how the model processes melody. When a melody is processed by memory for melodies, it is first processed in a relational code, where, for example, the relative distances in pitch are calculated rather than the absolute differences in pitch frequency – e.g., in Figure 5.3, instead of the first two notes being represented as A and Ab, they are represented as a fall of a semitone. The melody is also processed by RCM so as to determine the pitch accents and temporal accents of the melody; these are represented in Figures 5.4 and 5.5, respectively. M. R. Jones and Ralston (1991) argue that collocated pitch and temporal accents are more accurately remembered, comparatively, and the collocated pitch and temporal accents are represented in Figure 5.6.

![Figure 5.2. Melody based on the folk melody “The Suit Of Green”, in the key of C](image)
Figure 5.3. Melody based on the folk melody “The Suit Of Green” in the key of A, with the fourth note lengthened.

Figure 5.4. The temporally accented notes in the melody in Figure 5.2.

Figure 5.5. The pitch accented notes in the melody in Figure 5.2.

Figure 5.6. The dynamic accent structure of the melody in Figure 5.2.

The relational form of the melody, based around pitch and temporal accents, is sent to STMm. Depending on the length of the melody, and the length of time the melody is to be held in STMm, an amount of information about the melody is lost. It is unclear how much information is lost, because it is unclear to what extent melodies are chunked, and unclear what the capacity of the STMm. Lost information is less likely to be notes marked with accents than notes not marked with accents, and it is less likely to be notes marked with collocated accents than notes marked with either pitch or temporal accents. In a melody discrimination task, information from the first melody has to be held and compared to the second melody, which also has to be held in some form so it can be compared with the first melody. In a melody discrimination task using melodies with 16 notes, this effectively means that information representing up to 32 notes must be held in memory for the task to be completed.
perfectly. If STMm has a capacity of 4 notes, this effectively means that each chunk has to hold 8 bits of information. Thus, it is unsurprising that information is lost.

The information lost from the melody is reassembled by a redintegration process that, when melody pairs are transposed, uses veridical and schematic expectancies to reassemble the melody. In a 16 note melody, like that in Figure 5.2, with a short ISI, it may be that information from 9 notes is lost (see Figure 5.7 for an example of the remaining notes). In an 8 note melody, the amount of information needed in a chunk is significantly less, and thus more information, comparatively, is retained; for this reason LTM expectancy processes are less likely to influence memory for shorter melodies. In both short and long melodies, lost notes are reassembled by the redintegration process (see Figure 5.8), based on information about what notes are likely to be missing based on the schematic and veridical expectancies inherent in the melody. If the melody is familiar, veridical expectancies efficiently reassemble the melody; if the melody is less familiar, it is more likely that schematic expectancies are used to replace lost information. If there is no transposition between melodies, the original melody can also be compared with its representation in pitch memory, which can be used to reassemble the original melody. This melody is compared with the presentation of the second melody (see Figure 5.3), in which the fourth note is lengthened by one beat. If none of the information from the second melody appears to contradict information from the first melody, then the participant is likely to indicate that the melodies are the same. However, if information from the second melody is clearly different from the store and reassembled version of the first melody, then the participant is likely to detect a difference between the melodies.

![Figure 5.7. Retained information from the melody in Figure 5.2.](image)
5.8 Conclusions and Research Questions

Suggested by the Model

As the relationship between vSTM and memory for melodies is unclear, and models of vSTM are unsatisfactory for describing and predicting effects found in melody discrimination tasks, a model of relational memory for melodies has been described. This model of memory for melodies combines information from more auditory and perceptual processes (absolute pitch memory and the relational coding mechanism) and LTM information about melodies (schematic and veridical expectancies) into a relational representation of a melody. Several predictions made by this model are untested by published research, and will be investigated empirically in this thesis. Firstly, the model predicts that alterations to PIM will be more salient in LTM situations than alterations to melodic contour under conditions of transposition, as schematic expectancies predict melodic contour alterations but do not predict leaps, and so in a situation where the redintegration process needs to reassemble melodies, leaps are likely to be reassembled but alterations to contour are not. Secondly, the model predicts that basic temporal perceptual processes are responsible for the perceptual processing of duration in memory for melodies. Thirdly, the model predicts that metric information will appear to be influenced by LTM information under conditions of tempo transposition. Fourthly, the model predicts that melodies that resemble familiar melodies but differ slightly will be remembered poorly. Finally, the model predicts that collocated rhythm and pitch accents will be highly salient, under conditions of transposition in tempo or key. Chapters 5, 6, 7, 8, 9, 10, and 11 will detail experiments that investigate these hypotheses.
CHAPTER 6

Experiments 1a and 1b: Discriminating Pitch Interval Magnitude in Unfamiliar Tonal Melodies
6.1 Introduction

Chapter 6 details two experiments (1a and 1b) which have been designed to determine a) whether pitch interval magnitude (PIM) is salient in a melody discrimination task using transposition within melody pairs, and b) the nature of the cognitive mechanisms underlying the salience of PIM. Thus, in Experiment 1a, as detailed in Section 6.2, both musically-trained and untrained participants listened to pairs of long or short melodies in order to discriminate changes to a single tone in the comparison melody. These changes could involve changes to contour, increases in PIM, decreases in PIM, or changes to both contour and PIM. Experiment 1a showed that PIM was equally salient in short and long melodies, while contour declined in salience in long melodies. This suggested that the salience of PIM was due to the role of melodic expectancies rather than perceptual processing or short-term memory. Experiment 1b, as detailed in Section 6.3, tested the hypothesis that melodic expectancies were involved. Experiment 1b was largely similar to Experiment 1a, using identical stimuli, except that the changes occurred in the standard melody rather than the comparison melody. This prevents participants from accurately discriminating PIM, which is further evidence for the role of melodic expectancies.

6.1.1 General Objectives of Experiments 1a and 1b

The primary objective of the two experiments detailed in this chapter, Experiments 1a and 1b, is to determine how listeners process PIM in a melody discrimination task using unfamiliar tonal melodies. There is little research that has shed light on the role of PIM in memory for melodies, and none of this research has transposed melodies in key or varied melody length. Thus no available published research into PIM has eliminated the possibility that PIM is largely the result of pitch memory, or determined the relative roles of STM and LTM. Given the model of memory for melodies outlined in Chapter 5, there are four theories that predict how PIM might be processed in memory for melodies. Experiments 1a and 1b will empirically test these theories.
The first theory, Not Processed (NP) is that PIM is not deliberately processed by the model at all; e.g., the RCM does not mark PIM as less likely to be forgotten, and the redintegration process does not use LTM representations of PIM to reassemble melodies. If this theory is correct, then PIM should not be salient to listeners discriminating between unfamiliar key-transposed melodies in a melody discrimination task, regardless of whether melodies are short or long.

The second theory (RCM) is that PIM is processed by the relational coding mechanism, the part of the model that is also thought to process melodic contour. If this theory is correct, then the processing of PIM should be like the processing of melodic contour. Thus this second theory predicts that PIM should be more salient in short melodies compared to long melodies, and leaps in a melody should be more salient than steps in a melody, as leaps are considered pitch accents where steps are not. Furthermore, if this theory is correct, then participants with musical training should be more accurate at the task than those without musical training, but should not perform differently to non-musicians otherwise. Finally, if RCM is correct, note alterations to both contour and PIM should be more salient than note alterations to contour or PIM, in both short and long melodies.

The third theory that could account for the role of PIM in memory for melodies, SEP, is that PIM is recognised because a redintegration process uses LTM knowledge about the expectancies of melodies to reassemble the representation of the standard memory in order to compare it to the comparison melody. One difference between the predictions of SEP and RCM is that SEP predicts that there should be no difference between the salience of PIM in short versus long melodies, whereas the RCM predicts that PIM should be more salient in short melodies. A second difference is that SEP predicts that, in short melodies, alterations to both melodic contour and PIM should be more salient than either alterations to just melodic contour or alterations to just PIM; however, in long melodies, this theory predicts that alterations to both melodic contour and PIM will be more salient than alterations to melodic contour, but will not be more salient than alterations to PIM. However, like the RCM theory, the SEP theory firstly predicts that although there will be a main effect of musical training, there will be no interaction between musical training and melody type. Secondly, both theories predict that leaps should be more salient than steps.
The fourth theory (RCM+SEP) that could account for the role of PIM is the theory that that PIM is processed by both the relational coding mechanism and the redintegration process. This theory predicts that PIM will be discriminated more accurately than melodic contour in both long and short melodies, as it is represented both in STM and LTM, whereas melodic contour is represented only in STM. Additionally, this theory predicts that PIM will be discriminated more accurately in short melodies than in long melodies; this prediction is similar to those made by the RCM theory but different to the predictions of the SEP theory. Like both the RCM and SEP theories, this theory additionally predicts that leaps should be more accurately discriminated than steps in both short and long melodies. Additionally, like the RCM and SEP theories, this theory predicts no interaction between musical training and melody type.

### 6.2 Experiment 1a: Discriminating PIM and Contour in Short and Long Unfamiliar Melodies

#### 6.2.1 Aim and Design

This experiment used a variation of the melody discrimination task of Dowling (1978) in order to differentiate between the theories in Section 6.1 (e.g., NS, SEP, RCM, and RCM+SEP). In this experiment, the following variables were manipulated: length of melodies, melody alterations (i.e., alterations to melodic contour, PIM, or both), and level of musical training.

#### 6.2.1.1 Independent and Dependent Variables

In a 2 x 2 x 4 repeated measures design, participants completed a melody discrimination task. Participants were divided into two groups. One group of participants had less than two years of musical training, whereas the other group of
participants had more than five years of musical training; this was the between-groups independent variable. The within-groups independent variables were the number of notes in the melody (either short or long) and the type of melody alteration (either alteration of melodic contour direction, increase in PIM, decrease in PIM, or alteration of both melodic contour direction and PIM). The dependent variable in this experiment was accuracy, using the framework of signal detection theory (e.g., Swets, 1974). In a melody discrimination task, signal detection theory requires that the rate at which participants correctly discriminate a difference in a pair of melodies that are different – the Hit Rate – be moderated by the rate at which participants respond as if there is a difference when there is no difference – the False Alarm rate. In most cases, accuracy was calculated as Hit Rate minus False Alarm Rate (HR-FA); this provided a useful measure of the relative salience of the melody changes, incorporating information about false positives to avoid the possibility of response biases in the data. Where it needed to be established that a particular alteration was salient to participants, the Hit Rate and False Alarm Rate were compared; if the Hit Rate is significantly greater than the False Alarm Rate, it indicates that the melody alteration was salient.

### 6.2.1.2 Hypotheses

The hypotheses investigated in Experiment 1a are:

(i) That Hit Rates in response to PIM alterations will be higher than False Alarm Rates in both long and short melodies.

(ii) That HR-FA Rates in response to PIM alterations will be higher in short melodies than in long melodies.

(iii) That HR-FA Rates in response to melodies with simultaneous PIM and contour alterations will be higher than to melodies with either PIM or contour alterations in both short and long melodies.

(iv) That HR-FA Rates in response to both PIM alterations and contour alterations will be higher in participants with musical training than in participants without musical training, without an interaction between PIM and contour.
(v) That HR-FA Rates in response to contour alterations will be higher in short melodies than in long melodies.

6.2.2 Method

6.2.2.1 Participants

Participants in the musically untrained group were undergraduate psychology students who indicated that they had less than two years of musical training, had no hearing difficulties, did not have absolute pitch, and did not speak a tonal language; people who speak a tonal language (Stevens, Keller, & Tyler, unpublished) or have absolute pitch (Miyazaki, 2004) have different patterns of results in ways that suggest tonal language speakers and absolute pitch possessors may belong to substantially different populations (though see Schellenberg & Trehub, 2008). The results of four participants in the musically untrained group whose overall scores were at 50% or less (i.e., who were at the level of chance responding) were excluded from this sample as they may have misunderstood or not properly attempted the task. The 20 remaining participants (15 females and 5 males) had a mean age of 20.45 years ($SD = 4.11$) and reported an average of 0.65 years of musical training ($SD = 0.87$). Undergraduate psychology students received course credit for participation.

Participants in the musically trained group indicated that they had over five years of musical training, had no hearing difficulties, did not have absolute pitch, and did not speak a tonal language. Participants in this group were either undergraduate psychology students who received course credit, volunteers from the local community, or postgraduate students studying at the University of Western Sydney; this was necessary to have equivalent numbers in each group, as not enough undergraduates studying psychology had the necessary musical training. The 19 participants (12 females and 7 males) in this group had a mean age of 24.32 years ($SD = 7.80$) and reported an average of 10.52 years of musical training ($SD = 5.23$).
6.2.2.2 Materials

The stimulus materials were 44.1 KHz 1411 kbps stereo WAV files. These WAV files were based on monophonic, unaccompanied MIDI files of eight Irish and eight German folk melodies, taken from the KernScores website (http://kern.ccarh.org/, 2001) database. Irish and German folk melodies were used for their ecological validity in a Western tonal setting; these melodies were not isochronous, were strongly tonal, and highly expectable. In a pre-test, each of the 16 melodies used in this experiment were played to three listeners with over five years of musical training; no listener recognised any melody as a familiar melody. Thus these melodies were deemed unfamiliar to Australian participants. Melodies were created by taking the final 8 or 16 notes of a melody from the KernScores database. Some alterations were made to these melodies. In some melodies, the ending of the melody used several repeated tonic notes; in this experiment, some of these tonic tones were deleted to allow for greater manipulability of melodies. Secondly, three melodies used in Experiment 1a originally implied a minor key; notes in these melodies that implied a minor key (i.e., a minor third or minor sixth) were altered so that they implied a major key (i.e., to a major third or major sixth, respectively). See Appendix C for notated transcriptions of each melody used in this experiment; the WAV files used are on the data CD attached to this thesis.

Half of the melodies were 8 notes long (‘short melodies’); the other half of the melodies were 16 notes long (‘long melodies’). However, one 16 note melody was later omitted from the results due to errors in stimulus preparation (see Section 6.2.3), leaving eight short melodies and seven long melodies. The distinction between short and long melodies follows research by Edworthy (1985a), who found that melodic contour is more salient in melodies up to 9 notes long, and that interval is more salient in melodies over 11 notes long. All melodies were presented at a tempo of 120 beats per minute (bpm) using the time signature 4/4, following Dowling’s (1978) experiment. A tempo of 120 bpm is the default in most electronic instruments and software that incorporates an electronic metronome. This tempo is likely to be a standard tempo with which participants are familiar, and this tempo is in the range of tempos that allows the perception of melodies (Warren et al., 1991). 4/4 is the most common time signature in most Western genres of music. Because the proportion of
crotchets, quavers, and semiquavers in melodies differed, the temporal length of the melodies varied between 8 note and 16 note melodies. The lengths of 8 note melodies ranged from between 2.5 seconds to 5 seconds, while the lengths of 16 note melodies ranged from between 5 seconds to 9 seconds. All standard 8 note and 16 note melodies used in Experiment 1a were in the key of C major, following the experimental paradigm of Dowling (1978). All standard melodies ended on the tonic, middle C, in such a way that they appeared to resolve. No notes in Experiment 1a were accented in volume relative to other notes.

![Figure 6.1. Excerpt from ‘A Bhurillinn Bheasach’, an eight note melody in C used in Experiment 1a; see Appendix C for further examples.](image)

There were five types of comparison melody – those with a) a contour direction alteration, b) a step-to-leap alteration, c) a leap-to-step alteration, d) an alteration to both PIM and contour direction, and e) target melodies. All comparison melodies were similar to the standard melodies except that they had been either transposed up four semitones to the key of E major or had been transposed down three semitones to the key of A major, so that the pitch intervals between the notes remained the same but the absolute values of the notes changed. This followed the experimental paradigm of Dowling (1978).

In comparison melodies where there was an alteration to the original melody, this alteration did not alter the implied harmony of the original melody. Research by Schubert and Stevens (2006) suggests that participants with musical training are sensitive to changes to implied harmony in their judgements of melodic similarity. Therefore, in this experiment, if a melody implies the chord C major, for example, a G might be changed to an E in order to change the contour direction. Both the G and the E are consonant in the tonality of C major and a change from one to the other would not constitute a major change in implied harmony. In contrast, an F# is dissonant to the tonality of C major and does not imply a C major chord in this context; if a G note was changed to an F#, it would no longer imply a C major chord.
Thus, changes to melodies were made in such a way as to not change the implied harmony.

In comparison melodies where there was an alteration to the original melody, large differences between conditions in the serial position of the alteration (whether at the start, middle or end of melodies), in the metric position of the alteration (whether on the 1st or 3rd beat of a bar, the 2nd or 4th beat of a bar, or on an offbeat) and in the length of altered notes (i.e., whether semiquavers, quavers, crotchets or semibreves – at 120 beats per minute, a semibreve is 1 s long, a crotchet is 0.5 s long, a quaver is 0.25 s long and a semiquaver is 0.125 s long) were avoided where possible. However, because of the limited number of serial positions in these melodies where coherent sounding alterations could be made, and the limited amounts of pitches that could be changed without changing the implied harmony, the amount of these in various conditions was not always identical. Table 6.1 lists the alterations made to each melody.

Table 6.1. The note lengths of the 16 different melodies used in Experiments 1a and 1b, along with the serial position of the changed note, the metric position of the changed note (1=strong, 2=medium, 3=weak), and the note length, in seconds, of the changed note.

<table>
<thead>
<tr>
<th>Melody Name</th>
<th>Numbe r of Notes</th>
<th>Type of Change</th>
<th>Serial Position</th>
<th>Metric Position</th>
<th>Length of Changed Note(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Bhruinnillín Bhéasach</td>
<td>8</td>
<td>Contour Direction</td>
<td>1</td>
<td>2</td>
<td>0.75</td>
</tr>
<tr>
<td>A Bhruinnillín Bhéasach</td>
<td>8</td>
<td>Step to Leap</td>
<td>1</td>
<td>2</td>
<td>0.75</td>
</tr>
<tr>
<td>A Bhruinnillín Bhéasach</td>
<td>8</td>
<td>Leap to Step</td>
<td>5</td>
<td>1</td>
<td>0.75</td>
</tr>
<tr>
<td>A Bhruinnillín Bhéasach</td>
<td>8</td>
<td>Contour + Magnitude</td>
<td>6</td>
<td>3</td>
<td>0.25</td>
</tr>
<tr>
<td>As I Roved Out</td>
<td>16</td>
<td>Contour Direction</td>
<td>3</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>As I Roved Out</td>
<td>16</td>
<td>Step to Leap</td>
<td>12</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>As I Roved Out</td>
<td>16</td>
<td>Leap to Step</td>
<td>3</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>As I Roved Out</td>
<td>16</td>
<td>Contour + Magnitude</td>
<td>14</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Melody</td>
<td>Code</td>
<td>Repetition</td>
<td>Contour Direction</td>
<td>Step to Leap</td>
<td>Leap to Step</td>
</tr>
<tr>
<td>------------------------</td>
<td>------</td>
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<td>-------------------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>The Flower of Magherally</td>
<td>16</td>
<td>15</td>
<td>1</td>
<td>2</td>
<td>0.25</td>
</tr>
<tr>
<td>Lough erne shore</td>
<td>8</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Sláin le mbíogh</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Preab san ól!</td>
<td>8</td>
<td>1</td>
<td>3</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Roisin dubh</td>
<td>16</td>
<td>11</td>
<td>3</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Éamonn an chnuic(^8)</td>
<td>16</td>
<td>8</td>
<td>2</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>

\(^8\) Responses to this melody were later omitted from data analysis because of errors in stimulus preparation.
<table>
<thead>
<tr>
<th>Dance</th>
<th>Steps</th>
<th>Contour Direction</th>
<th>Step to Leap</th>
<th>Leap to Step</th>
<th>Contour +</th>
<th>Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Éamonn an chnuic</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Dreikönigslied</td>
<td>8</td>
<td>Contour Direction</td>
<td></td>
<td></td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Dreikönigslied</td>
<td>8</td>
<td>Step to Leap</td>
<td></td>
<td></td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Dreikönigslied</td>
<td>8</td>
<td>Leap to Step</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Dreikönigslied</td>
<td>8</td>
<td>Contour +</td>
<td></td>
<td></td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Lazarus und der Prasser</td>
<td>16</td>
<td>Contour Direction</td>
<td></td>
<td></td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Lazarus und der Prasser</td>
<td>16</td>
<td>Step to Leap</td>
<td></td>
<td></td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Lazarus und der Prasser</td>
<td>16</td>
<td>Leap to Step</td>
<td></td>
<td></td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>Lazarus und der Prasser</td>
<td>16</td>
<td>Contour +</td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Ach Schatz, wo fehlt es dir</td>
<td>8</td>
<td>Contour Direction</td>
<td></td>
<td></td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Ach Schatz, wo fehlt es dir</td>
<td>8</td>
<td>Step to Leap</td>
<td></td>
<td></td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Ach Schatz, wo fehlt es dir</td>
<td>8</td>
<td>Leap to Step</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ach Schatz, wo fehlt es dir</td>
<td>8</td>
<td>Contour +</td>
<td></td>
<td></td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Vierter Tanz</td>
<td>16</td>
<td>Contour Direction</td>
<td></td>
<td></td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Vierter Tanz</td>
<td>16</td>
<td>Step to Leap</td>
<td></td>
<td></td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Vierter Tanz</td>
<td>16</td>
<td>Leap to Step</td>
<td></td>
<td></td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>Vierter Tanz</td>
<td>16</td>
<td>Contour +</td>
<td></td>
<td></td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>Schlangenköchin</td>
<td>16</td>
<td>Contour Direction</td>
<td></td>
<td></td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Schlangenköchin</td>
<td>16</td>
<td>Step to Leap</td>
<td></td>
<td></td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>Schlangenköchin</td>
<td>16</td>
<td>Leap to Step</td>
<td></td>
<td></td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Schlangenköchin</td>
<td>16</td>
<td>Contour +</td>
<td></td>
<td></td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Schöner Meie</td>
<td>16</td>
<td>Contour Direction</td>
<td></td>
<td></td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Schöner Meie</td>
<td>16</td>
<td>Step to Leap</td>
<td></td>
<td></td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Schöner Meie</td>
<td>16</td>
<td>Leap to Step</td>
<td></td>
<td></td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>Contour +</td>
<td>13</td>
<td>3</td>
<td>0.5</td>
<td></td>
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<td>----------------</td>
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</tr>
<tr>
<td>Schöner Meie</td>
<td>16</td>
<td>Contour +</td>
<td>13</td>
<td>3</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Bettelfrau und Bettelmann</td>
<td>8</td>
<td>Contour Direction</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Bettelfrau und Bettelmann</td>
<td>8</td>
<td>Step to Leap</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Bettelfrau und Bettelmann</td>
<td>8</td>
<td>Leap to Step</td>
<td>7</td>
<td>3</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Bettelfrau und Bettelmann</td>
<td>8</td>
<td>Contour +</td>
<td>7</td>
<td>3</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Des Lindenwirts Rösel</td>
<td>8</td>
<td>Contour Direction</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Des Lindenwirts Rösel</td>
<td>8</td>
<td>Step to Leap</td>
<td>6</td>
<td>2</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Des Lindenwirts Rösel</td>
<td>8</td>
<td>Leap to Step</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Des Lindenwirts Rösel</td>
<td>8</td>
<td>Contour +</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

In contour alteration melodies, the pitch of one note in the melody was altered so that the contour direction was changed from up to down, or from down to up. Alterations to contour direction did not alter PIM. In step-to-leap alteration melodies, a step in the melody (i.e., an interval of three or less semitones) was altered so that it became a leap (i.e., an interval of four or more semitones), without changing the contour direction. It should be pointed out that a step is usually defined as the distance between two adjacent notes on a key scale (Grove Music Online, 2007); although in a minor scale this distance can be three semitones, steps are usually pitch distances of one or two semitones, whereas a leap is usually a pitch distance of more than two semitones. Experiment 1a followed Stevens and Latimer (1992) in defining steps as three or less semitones and leaps as four or more semitones. This definition was partly because melodies in the KernScores database that could be altered so that a leap became a step without altering the implied harmony were rare, but also because it is unclear whether people perceive steps as being categorically different to leaps and unclear where the perceptual boundary between steps and leaps lies. The definition of Stevens and Latimer (1992) may be supported by research suggesting that, in the perception of prosody, changes to fundamental frequency generally become perceptible at the equivalent of between 2 and 3 semitones (‘t Hart, 1981). Leap-to-
step alteration melodies were similar to step-to-leap alteration melodies, except that instead of changing a step in the melody to a leap, a leap in the melody was changed to a step. In PIM and contour alteration melodies, both the direction and magnitude of one note in the melody was altered. A step up therefore became a leap down, and vice versa; similarly, a step down became a leap up, and vice versa. It should be pointed out that changing one note in comparison melodies changes two relationships between notes, and that these changes refer to the note relationship that is temporally first. Alterations in melodic contour or PIM to the second note relationship were avoided where possible within the limitations of the melodies used. However, alterations to the melodic contour in the second note relationship did not occur in the step-to-leap or leap-to-step alteration conditions. Neither did alterations to PIM in the second note relationship occur in the melodic contour alteration condition.

6.2.2.3 Apparatus

The stimuli were manipulated using the software Midisoft Studio 3.10 and then converted to 44.1 kHz stereo WAV files. Stimuli were presented to participants through Koss UR-20 headphones, using an Acer Laptop, and the experimental software DMDX 3.1. Statistics were tabulated using Microsoft Excel XP, and were analysed using WinPsy2000.

6.2.2.4 Procedure

The experimenter began by giving the participant an information sheet and obtaining consent, according to the requirements of the University of Western Sydney Human Research Ethics Committee (see Appendix G for the information sheet and consent form). Participants then filled in a questionnaire that had questions about their age, gender, handedness, level of musical training, experience with languages other than English, and their possession of absolute pitch (see Appendix G). The experimenter explained that all comparison melodies, even those that are otherwise the same, were key transpositions of the standard melodies, and explained that key transpositions thus did not count as different in this experiment. Using a Roland KF-90 Digital Piano, the
experimenter then gave examples of transposition, and of same and different pairs of melodies using well-known nursery rhymes such as “Mary Had A Little Lamb” and “Twinkle Twinkle Little Star”. Before starting the experimental trials, participants were presented with eight practice trials, all of which used an eight note melody based on a folk melody from the KernScores website database not used in the experimental trials (see Appendix C). In the practice trials, participants were given corrective feedback. No feedback was given in the experimental trials.

On each experimental trial, participants heard a pair of melodies, with an inter-stimulus interval (ISI) of 1 s. Participants were asked to press a button on the left side of a computer keyboard marked “diff” (the left shift key), immediately after they heard any difference between the pair of melodies, or to press a button on the right side computer keyboard marked “same” (the right shift key) if they heard no difference.

If each participant heard a trial corresponding to every possible stimuli pair, with equivalent amounts of same and different trials, it would have led to a 90-100 minute session for each participant; this was considered beyond the attention span of most adults. Thus, two separate sets of stimuli were created. These stimuli sets were identical except that the comparison melody in any one pair of melodies was transposed to the key of E major in one set and transposed to the key of A major in the other set. Participants were randomly assigned to a stimulus set. These stimuli sets were not treated as different in statistical analysis. Each participant received one set of 128 experimental trials with a different randomised presentation order. Over the course of the experiment, each participant heard each melody, or a variation upon that melody, 16 times. There were equal proportions of same trials and different trials, but participants were given no information about the proportion of correct trials. Each stimulus set had one trial that compared each of the 16 standard melodies to each of a: a) target comparison melody; b) contour alteration comparison melody; c) step-to-leap alteration comparison melody; d) leap-to-step alteration melody; and e) pitch interval magnitude and contour alteration melody; thus there were 16 observations per condition. The experiment took 50 minutes to complete.
Figure 6.2. The top of the figure shows the length of different phases of the experiment, whereas the bottom of the figure shows the format of a typical experimental trial. ‘1s’ represents the 1 second pause between the standard and comparison melody, whereas the 10s represents the 10 seconds from the start of the comparison melody within which participants have to respond.

6.2.3 Results

A selection criterion was applied to the results – accuracy data from participants who performed at lower than chance level overall were not included in the results, as those participants either did not seriously attempt the task or misunderstood the task. The results of four participants without musical training were excluded under this selection criterion, which left a final sample size of 39 once results from the two stimuli sets were combined. Additionally, because of errors in stimulus preparation detected after the completion of the experiment, it was necessary that participants’ responses to the 16-note melody “Éamonn An Chnuic” be omitted from the analysis. An alpha level of .05 was used for all statistical tests.

The first hypothesis, derived from both the RCM and the SEP theories, predicted that all participants can discriminate between both short and long melodies on the basis of PIM. In short melodies with step-to-leap alterations, the hit rate, where participants
correctly indicated that the two melodies were different ($M = .55, SD = .22$), was significantly greater than the False Alarm Rate, where participants incorrectly indicated that the two melodies were different ($M = .21, SD = .16$), $F(1,38) = 78.87, p < .05, d = 1.73$. Similarly, in short melodies with leap-to-step alterations, the hit rate ($M = .44, SD = .22$) was significantly greater than the False Alarm Rate ($M = .21, SD = .16$), $F(1,38) = 29.88, p < .05, d = 1.20$. Turning to long melodies with step-to-leap alterations, the hit rate ($M = .62, SD = .19$) was again significantly greater than the False Alarm Rate ($M = .27, SD = .14$), $F(1,38) = 73.42, p < .05, d = 1.73$. Finally, in long melodies with leap-to-step alterations, the hit rate ($M = .4, SD = .19$) was significantly greater than the False Alarm Rate ($M = .27, SD = .14$), $F(1,38) = 78.87, p < .05, d = 0.65$. Especially in melodies with step-to-leap alterations, these are large effect sizes – 0.8 is usually considered a large effect (Cumming & Finch, 2001); thus the results indicate that the alternative hypothesis is supported, that participants could discriminate between both short and long melodies on the basis of either increases or decreases to PIM.

![Figure 6.3. Mean Hit Rate minus False Alarm rates to different melody alterations in short and long melodies in Experiment 1a (n = 39), with error bars representing standard error of the mean; StL refers to a Step-to-Leap alteration, LtS refers to a Leap-to-Step alteration, CA](image-url)
refers to a Contour Alteration and CPIMA refers to a simultaneous alteration to contour and PIM.

The RCM hypothesis predicted that participants should be more accurate at detecting increases to PIM in short melodies than in long melodies; the SEP hypothesis predicts no change in accuracy based on length. In a 3-Way Repeated Measures Analysis of Variance, there was no significant difference between the HR minus FA rate to step-to-leap alterations in short melodies ($M = .44$, $SD = .22$) compared to long melodies ($M = .40$, $SD = .27$), $F(1,37) = 0.84$, $p = n.s.$; this can be seen in Figure 6.3. Thus the SEP hypothesis was supported.

The RCM hypothesis predicted that participants would be more accurate at detecting alterations to melodies with simultaneous alterations to both PIM and contour in both long and short melodies than alterations to just PIM or contour. In contrast, the SEP hypothesis predicted that melodies with simultaneous alterations to both PIM and contour will be more salient in short melodies, but that in long melodies, step-to-leap alterations will be equally salient as melodies with alterations to both PIM and contour. As shown in Figure 6.3, in short melodies, alterations to both PIM and contour ($M = .60$, $SD = .24$) were significantly more salient than increases to PIM ($M = .44$, $SD = .22$), $F(1,37) = 29.01$, $p < .05$, $d = 0.69$. Additionally, alterations to both PIM and contour ($M = .60$, $SD = .24$) were significantly more salient than alterations to contour direction ($M = .54$, $SD = .24$), $F(1,37) = 5.39$, $p < .05$, $d = 0.24$. This was also the case in long melodies; alterations to both PIM and contour ($M = .43$, $SD = .31$) were significantly more salient than alterations to contour direction ($M = .29$, $SD = .2$), $F(1,37) = 7.49$, $p < .05$, $d = 0.56$. However, in long melodies, there was no significant difference between the salience of alterations to both PIM and contour ($M = .43$, $SD = .31$) and increases to PIM ($M = .40$, $SD = .27$), $F(1,37) = 0.29$, $p = n.s.$.

Thus, the results support the SEP hypothesis in regards to the relative salience of alterations to both PIM and contour in comparison to either PIM and contour in short or long melodies.

Both the RCM and SEP hypotheses predict that increases in PIM will be more salient than decreases in PIM across melodies. Increases in PIM in short melodies ($M = .44$, $SD = .22$) and in long melodies ($M = .39$, $SD = .26$) were significantly more salient
than decreases in PIM in short melodies ($M = .32, SD = .26$) and in long melodies ($M = .14, SD = .20$), $F(1,37) = 88.48, p < .05, d = 0.84$. This provides support for both the RCM and SEP hypotheses.

The RCM hypothesis predicts that musicians will discriminate alterations to PIM more accurately than non-musicians, and that there will be no interaction between musical training and melody type (contour vs PIM); in contrast, the SEP hypothesis predicts that musicians will discriminate alterations to PIM more accurately than non-musicians, but that there will be an interaction between musical training and melody alteration type. Despite participants with musical training having a mean HR minus FA rate of .43 ($SD = .21$), and participants without musical training having a mean HR minus FA rate of .34 ($SD = .24$), there was no main effect of musical training, $F(1,37) = 2.74, p = n.s.$, though the 95% confidence intervals of $d$ (-0.09 and 0.89) were wide, suggesting variation across participants within groups. This suggests that, although there was no significant difference between the performance of musicians and non-musicians, overall, this may be a side-effect of a lack of statistical power.

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**Table 6.2. Hypotheses in Experiment 1a and whether they were supported**

<table>
<thead>
<tr>
<th>#</th>
<th>Hypothesis</th>
<th>Supported?</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>That Hit Rates in response to PIM alterations will be higher than False Alarm Rates in both long and short melodies</td>
<td>Yes</td>
</tr>
<tr>
<td>II</td>
<td>That Hit Rate minus False Alarm Rates in response to PIM alterations will be higher in short melodies than in long melodies</td>
<td>No</td>
</tr>
<tr>
<td>III</td>
<td>That Hit Rate minus False Alarm Rates in response to melodies with simultaneous PIM and contour alterations will be higher than HR-FA Rates to melodies with either PIM or contour alterations in both short and long melodies</td>
<td>Partially</td>
</tr>
<tr>
<td>IV</td>
<td>That Hit Rate minus False Alarm Rates in response to both PIM alterations and contour alterations will be higher in participants with musical training than in participants without musical training, without an interaction between PIM and contour</td>
<td>Yes</td>
</tr>
</tbody>
</table>
6.2.4 Discussion

The theory that participants’ ability to detect differences in PIM is due to the redintegration process (SEP) appears to be the most plausible explanation of most of the results of Experiment 1a. Both SEP and RCM, the theory that the ability to detect differences in PIM is due to a relational coding mechanism, predicted that increases in PIM would be more salient than decreases in PIM; this hypothesis was supported by the data. However, where SEP predicted that there would be no difference between the salience of increases in PIM in long melodies compared to short melodies, RCM predicted that the salience would decrease as melody length increases. As the data suggested no difference in salience, SEP was supported. SEP also predicted that, although increases in PIM would be less salient than alterations to both PIM and contour direction in short melodies, in long melodies increases in PIM would be as salient as alterations to both PIM and contour direction. In contrast, RCM predicted no change in their comparative salience between short melodies and long melodies. As three out of three hypotheses derived from SEP were supported, whereas one out of three hypotheses of RCM was supported, it suggests that SEP provides a better explanation of participants’ ability to detect alterations in PIM than RCM.

However, neither theory predicted the lack of a main effect of musical training. The finding that musicians were better at detecting contour alterations than at detecting PIM increases in short melodies was the opposite to the prediction made by SEP, that musical training would make PIM increases comparatively more salient, especially in long melodies; no interaction between training and melody change type was found in long melodies. Assuming that the SEP theory of participants’ ability to detect PIM increases is correct, this suggests that musicians are able to more efficiently use their limited short term memory capacity. However, it also suggests that musicians have no advantage over those without musical training in terms of their ability to integrate musical LTM knowledge to reassemble degraded musical traces in STM. It is important to note that alterations to contour or PIM in melodies in this experiment did
not change implied harmony; that Schubert and Stevens (2006) found that musicians were sensitive to implied harmony suggests that much of musicians’ advantage over nonmusicians in remembering musical stimuli may be due to improved perception of tonality.

The present experiment, however, does not conclusively prove that a redintegration process using LTM knowledge about melodic expectations is responsible for the salience of PIM to participants. The SEP theory makes the assumption that the folk melodies used in this experiment were predictable melodies. However, as the folk melodies used in this experiment were not isochronous, but instead were rhythmically complex, and as rhythm and pitch may interact in memory (e.g., M. R. Jones, 1993) it is difficult to objectively determine the expectancy of a particular melody in the absence of a metric of musical expectations that measures not only pitch but also time. It is possible that some melodies in this experiment were musically unexpected in some way. Thus, the SEP theory must be tested with further experimental variations designed with an intention to manipulate the expectancies implied by the melodies.

6.3 Experiment 1b: Discriminating PIM and Contour in Short and Long Melodies, With Reversed Within-Trial Order

Experiment 1b was devised to further test the theory that best explained the data in Experiment 1a, the SEP theory, by manipulating the expectedness of the melodies. If the SEP theory is an accurate explanation of the PIM data, reversing the order of presentation of the melodies considered comparison and standard melodies in Experiment 1a (e.g., if the original melodies were in the standard melody, and the altered melody in the comparison) within a trial should make the comparison melody more expected, and thus make PIM harder to discriminate.

It is assumed for this experiment that unaltered excerpts from the ends of folk song melodies, which have traditionally been transmitted orally, should have high levels of melodic expectancy. The ‘Chinese whispers’ inherent in oral transmission should
ensure that the unexpectedness of folk song melodies is minimised in comparison, for example, to Western art music, as Western art music is typically based on notated musical scores that presumably aid memory for complex content. In contrast, and especially considering the redundancy inherent in most music (Boltz, 1999), excerpts where notes had been altered will almost certainly be more unexpected, even when implied harmony has been controlled. In any trial in a melody discrimination task, there are two presentations of melodies that must be held in memory – the standard melody and the comparison melody. Because the standard melody is presented first, it is more likely to be subject to decay and/or interference than the comparison melody presented second. Thus, if unfamiliar folk songs, with high levels of schematic expectancy, are presented to participants as the comparison melody rather than as the standard melody (i.e., presented first), the unexpected aspects of what will now be the standard melody may be forgotten before the melody is reassembled by the redintegration process. Although the LTM knowledge used to process PIM was facilitatory in Experiment 1a, it is predicted that such knowledge will be a hindrance in Experiment 1b, especially in long melodies.

It should be noted that the act of reversing the order of presentation of melodies within a trial turns a step-to-leap alteration into a leap-to-step alteration. In this experiment, the reversed order trials equivalent to step-to-leap alterations (e.g., changing a note relationship from G3-A3 to G3-C4) will be referred to as reversed-step-to-leap alterations (e.g., changing a note relationship from G3-C4 to G3-A3); similarly, the reversed order trials equivalent to a leap-to-step alteration (e.g., changing a note relationship from G3-C4 to G3-A3) will be referred to as a reversed-step-to-leap alterations (e.g., changing a note relationship from G3-A3 to G3-C4). However, it is not expected in Experiment 1b that this reversal will have much impact on the results of this study, as the within-trial order reversal is expected to remove the salience of PIM.

### 6.3.1 Design and Variables

In a 2 x 4 repeated measures design, participants completed a melody discrimination task. The independent variables were the length of the melody, and the kind of
alteration made to the melody. The dependent variables were a) where the salience of a particular melody alteration is being determined, the Hit Rate compared to the False Alarm Rate; and b) where the relative salience of particular melody alterations are being compared, the Hit Rate minus False Alarm Rate. In this design a Hit is considered to be where a participant has correctly determined that the two melodies presented are different, whereas a False Alarm is considered to be where a participant has falsely decided that the two melodies presented are different.

6.3.1.1 Hypotheses

The hypotheses in this experiment are derived from the theory that if PIM is encoded using LTM knowledge, then reversing the presentation order of trials will delete this effect. Specifically:

(i) That Hit Rates in response to melodies with PIM alterations will not be higher than False Alarm Rates in either short or long melodies.

(ii) That HR-FA Rates in response to melodies with simultaneous PIM and contour alterations will be higher than in response to melodies with only PIM alterations, in both short and long melodies.

(iii) That HR-FA Rates in response to melodies with contour alterations will be higher in short melodies than in long melodies.

6.3.2 Method

6.3.2.1 Participants

In Experiment 1b, it was unnecessary to recruit participants with musical training or differentiate between musically trained and untrained participants, as Experiment 1a had shown that there was no dramatically different pattern of results across conditions. Participants in Experiment 1b were undergraduate psychology students who had less than two years of musical training, had no hearing difficulties, did not have absolute pitch, and did not speak a tonal language. Participants additionally had not participated in Experiment 1a. 19 participants (17 females and 2 males) had a
mean age of 24 years ($SD = 11.22$) and reported an average of 0.61 years of musical training ($SD = 0.79$). Undergraduate psychology students received course credit for participation.

6.3.2.2 Materials

Materials used in Experiment 1b were identical to those used in Experiment 1a. That is, melodies derived from Irish and German folk melodies were either 8 or 16 notes long, were in the time signature 4/4 and were presented at a tempo of 120bpm. Some melodies had alterations to melodic contour direction, increases in PIM, decreases in PIM or alterations to both melodic contour direction and PIM; additionally, changes to implied harmony were avoided.

6.3.2.3 Apparatus

The apparatus used in Experiment 1b were identical to that used in Experiment 1a.

6.3.2.4 Procedure

The procedure used in Experiment 1b was identical to that used in Experiment 1a - participants completed a melody discrimination task where they were asked to determine whether two transposed melodies were the same or different - with the exception that the order of presentation was reversed in every trial compared to Experiment 1a. For example, the comparison melody in a trial in Experiment 1a was the standard melody in the equivalent trial in Experiment 1b, whereas the standard melody in a trial in Experiment 1a was the comparison melody in the equivalent trial in Experiment 1b (see Figure 6.4).
6.3.3 Results

To analyse the data in Experiment 2, a 2-Way Analyses of Variance was run, comparing the Hit Rate of each melody alteration condition to the False Alarm Rate to same melody pairs using that particular melody alteration (i.e., melody pairs where both melodies have the same alteration). This analysis was used in order to establish whether participants were able to discriminate any of the melody alterations. If it was established that participants were able to discriminate some melody alterations, these alterations were compared using further 2-Way Analyses of Variance. As in Experiment 1a, because of errors in stimulus preparation detected after the completion of the experiment, participants’ responses to the 16-note melody “Éamonn An Chnuic” were omitted from the analysis. An alpha level of .05 was used for all statistical tests.
The first hypothesis in this experiment was that Hit Rates in response to melodies with PIM alterations would not be higher than False Alarm Rates in either short or long melodies. In short reversed-step-to-leap melodies, the Hit Rate ($M = .34, SD = .23$) was not significantly different from the False Alarm Rate ($M = .26, SD = .14$), $F(1,18) = 2.744, p = n.s.$ In short reversed-leap-to-step melodies, the Hit Rate ($M = .29, SD = .19$) was not significantly different from the False Alarm Rate ($M = .26, SD = .14$), $F(1,18) = 0.40, p = n.s.$ In long reversed-step-to-leap melodies, the Hit Rate ($M = .42, SD = .17$) was not significantly different from the False Alarm Rate ($M = .51, SD = .05$), $F(1,18) = 2.36, p = n.s.$ In long reversed-leap-to-step melodies, the Hit Rate ($M = .45, SD = .21$) was not significantly different from the False Alarm Rate ($M = .51, SD = .15$), $F(1,18) = 0.794, p = n.s.$ Thus this hypothesis was supported in both reversed-step-to-leap melodies and reversed-leap-to-step melodies, and in both short and long melodies.

As hypothesised, there was a significant difference between the Hit Rate of short contour alteration melodies ($M = .39, SD = .16$) and the False Alarm Rate to short melodies ($M = .26, SD = .14$), $F(1,18) = 9.26, p < .05, d = 0.67$. Similarly, there were significant differences between the Hit Rate, in short melodies, to contour and PIM alteration melodies ($M = .49, SD = .28$) and the False Alarm Rate to same melodies ($M = .26, SD = .14$), $F(1,18) = 12.52, p < .05, d = 1.21$. 
Figure 6.5. Mean Hit Rate minus False Alarm Rates to different melody alterations in short and long melodies in Experiment 1b (n = 19), with error bars representing standard error of the mean; StL refers to a reversed-Step-to-Leap alteration, LtS refers to a reversed-Leap-to-Step alteration, CA refers to a Contour Alteration and CPIMA refers to a simultaneous alteration to contour and PIM.

The second hypothesis was that HR-FA Rates in response to melodies with simultaneous PIM and contour alterations would be higher than in response to melodies with PIM alterations, in both short and long melodies. As can be seen in Figure 6.5, short reversed-step-to-leap melodies (M = .08, SD = .21) were not significantly different to short PIM and contour alteration melodies (M = .23, SD = .18), $F(1,18) = 4.21, p = n.s.$ Short reversed-leap-to-step melodies (M = 0.03, SD = 0.21), however, were discriminated significantly less often than short PIM and contour alteration melodies (M = 0.23, SD = 0.18), $F(1,18) = 7.560, p < .05. d = 1.01$. Long reversed-step-to-leap melodies (M = -0.02, SD = 0.14), were discriminated significantly less often than long PIM and contour alteration melodies (M = .14, SD = 0.17), $F(1,18) = 9.08, p < .05, d = 0.82$. Long reversed-leap-to-step melodies (M = .01, SD = .20) were discriminated significantly less often than long PIM and contour alteration melodies (M = .14, SD = .17), $F(1,18) = 4.74, p < .05, d = 0.64$. Thus, the hypothesis that participants would be more accurate at PIM and contour alteration
melodies than at PIM alteration melodies was supported in long melodies, and supported in short reversed-leap-to-step melodies, but not supported in short reversed-step-to-leap melodies. That it was not supported in short-reversed-step-to-leap melodies may be because of a floor effect evident in this experiment; the $F$ value for the comparison between those melodies and PIM and contour alteration melodies was 4.21, which was only just below the $F$ value needed for significance at the .05 level, which was 4.41. The floor effect is evident in the wide range of the 95% Confidence Intervals of the Cohen’s $d$ statistic; the $d$ statistic on this comparison is 0.78, which would usually indicate a medium to large effect; however, the 95% CI values for the $d$ statistic are -0.38 and 1.94 suggesting a floor effect; the actual effect size may be between a medium reversed effect (e.g., -0.38) and an exceedingly large effect (e.g., 1.94).

The third hypothesis was that HR-FA Rates in response to melodies with contour alterations would be higher in short melodies than in long melodies. As shown in Figure 6.5, contour alterations in short melodies ($M = 0.13$, $SD = 0.19$) were more salient to participants than contour alterations in long melodies ($M = 0.05$, $SD = 0.19$), however this difference was not statistically significant, $F(1,18) = 2.67, p = n.s.$

Again, that this prediction was not statistically significant may be because of the floor effect evident in this experiment; the $d$ value for this comparison was 0.403, with a 95% CI range from -0.361 to 1.167. Thus, though there was a floor effect, there may be some support for this hypothesis.

*Table 6.3. Hypotheses in Experiment 1b and whether they were supported.*

<table>
<thead>
<tr>
<th>#</th>
<th><strong>Hypothesis</strong></th>
<th><strong>Supported?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>That Hit Rates in response to melodies with PIM alterations will not be higher than False Alarm Rates in either short or long melodies</td>
<td>Yes (Null)</td>
</tr>
<tr>
<td>II</td>
<td>That HR-FA Rates in response to melodies with simultaneous PIM and contour alterations will be higher than in response to melodies with PIM alterations, in both short and long melodies.</td>
<td>Partially</td>
</tr>
<tr>
<td>III</td>
<td>That HR-FA Rates in response to melodies with contour alterations will be higher in short melodies than in long melodies.</td>
<td>Yes</td>
</tr>
</tbody>
</table>
6.3.4 Discussion

The results of Experiment 1b are broadly consistent with the hypothesis that if PIM is processed by a redintegration process, PIM should not be salient in a task with reversed presentation order. The first hypothesis was supported; there was no statistical difference between the False Alarm Rate and the Hit Rate with either reversed-leap-to-step or reversed-step-to-leap melodies in either short or long melodies to PIM in either short or long melodies. PIM was therefore not salient in a task with reversed presentation order. However, the Hit Rates of both melodic contour alterations and contour and PIM alterations were significantly different to the False Alarm Rates recorded in response to short melodies.

Additionally, the second hypothesis was supported; participants were significantly more accurate in their discrimination of melodies with alterations to both PIM and contour than their discrimination of melodies with alterations to just PIM, in long melodies. This was unsurprising, considering the lack of a difference between the Hit Rate and the False Alarm Rate in melodies with alterations to PIM. As anticipated, this finding is opposite to the equivalent finding in Experiment 1a, where, in long melodies, there was no significant difference in accuracy between step-to-leap alteration melodies and PIM and contour alteration melodies.

However, the third hypothesis – that alterations to melodic contour would be more salient in short melodies than in long melodies – received only weak support; participants were more accurate at discriminating alterations to melodic contour in short melodies than in long melodies, but this only approached significance at the .05 level. It is likely that this lack of significance was due to a floor effect – overall levels were lower than in Experiment 1a.

It must be pointed out that the general floor effect evident in the results of Experiment 1b means that conclusions about the relative salience of different kinds of melodic alterations are highly problematic. However, the general floor effect, at least, illustrates that LTM knowledge of melodies is important to short term memory for
melodies in experiments like Experiment 1a; the presence of this floor effect in
Experiment 1b but not in Experiment 1a clearly shows that alterations to melodies are
much less salient if the LTM knowledge of melodies held by non-musician
participants hinders rather than facilitates discrimination. Because Experiment 1b did
not test musically trained participants, it is unclear whether a similar floor effect
would be in effect with musically trained participants.

There was no difference between Hit Rates and False Alarm Rates of either reversed-
step-to-leap melodies or reversed-leap-to-step melodies in this experiment.
Additionally, the HR-FA of PIM and contour alteration melodies were significantly
greater than the HR-FA of alterations to PIM in long melodies. These results therefore
strongly suggest that the process responsible for detecting PIM uses LTM knowledge
about expectancies.

6.4 General Discussion

Experiments 1a and 1b, taken together, provide evidence for the SEP theory, that PIM
is salient to memory for melodies because of the role of LTM processes. Firstly, in
Experiment 1a, leaps were more salient than steps. Secondly, in Experiment 1a, there
was no difference between the salience of step-to-leap alterations in short melodies
and in long melodies. Thirdly, in long melodies in Experiment 1a, there was no
difference between the salience of step-to-leap alterations and alterations to both
contour and PIM. Fourthly, in Experiment 1b, reversing the order of presentation
within a trial, which was expected to inhibit any response based on LTM knowledge,
as the more unexpected melody was presented first, greatly reduced the salience of
PIM to the point that there was no significant difference between Hit Rates and False
Alarm Rates in both short melodies and long melodies and in both step-to-leap
melodies and leap-to-step melodies.

Similarly, Experiments 1a and 1b provide further experimental support for the
assertion in the model of relational memory for melodies that the processing of
melodic contour in memory for melodies is largely based on the relational coding mechanism. This experiment replicated the findings of Edworthy (1985a), who found that reaction time to interval alterations were faster than reaction time to contour alterations in long unfamiliar tonal melodies, but longer in short melodies. In Experiment 1a, participants were more accurate at discriminating alterations to contour in short melodies than in long melodies. A similar effect in Experiment 1b did not reach significance, perhaps because of a floor effect, but followed the same trend. Additionally, although reversing presentation order within a trial eliminated the salience of PIM, it did not eliminate the salience of melodic contour; there was still a significant difference between Hit Rates and False Alarm Rates in short melodies for both melodies with contour alterations and melodies with both contour and PIM alterations. This lack of elimination of the salience of melodic contour suggests that, where PIM must be based on LTM knowledge, the discrimination of melodic contour must at least partially be based on STM processing.

In terms of the model outlined in Chapter 5, Experiments 1a and 1b suggest that the relational coding mechanism does not mark alterations to PIM in such a way that they are less likely to decay in short term memory for melodies; however, these experiments do suggest that alterations to melodic contour are marked in such a way. Instead, however, the results in these experiments show that processing of PIM is facilitated by the redintegration process, which uses information from either schematic or veridical expectancies to reassemble decayed information in the standard melody in a melody discrimination task so that a memory trace of the standard melody can be compared to the relationally-encoded information about the comparison melody.

If the results of Experiments 1a and 1b are valid and replicable, there are considerable theoretical and empirical implications for research by Peretz and colleagues (e.g., Liegeois-Chauvel et al, 1998; Peretz, 1990; Peretz & Coltheart, 2003), M. R. Jones (1993), Ockelford (2007), and Berz (1995). That the salience of PIM in a discrimination task appeared to be due to a redintegration process using LTM knowledge suggests that the usual distinction made between melodic contour and interval reported in research like that of Edworthy (1985a) and Peretz (1990) is more likely a distinction between purely STM or perceptual processes and processes using
LTM knowledge; melodic contour appears to be more based on purely STM and perceptual processes whereas interval information and PIM appears to be based more on LTM processes. Secondly, that the salience of PIM in a discrimination task appeared to be due to a redintegration process using LTM knowledge suggests that PIM is not an important aspect of dynamic accent structure, contrary to the claims of M. R. Jones (1993) and colleagues, as their conception of dynamic accent structure is as a dynamic note-to-note STM or perceptual process. In regards to models of memory for melodies, the results of these experiments suggest that the distinction in Peretz and Coltheart’s (2003) model between submodules for contour processing and interval processing is more accurately a distinction between LTM and STM knowledge. In the context of this model, it would be informative to see whether cases of atonalia (Peretz, 1993) or amelodia to interval alterations (e.g., Peretz, 1990) are due to a loss of information from LTM expectancies, or due to a faulty redintegration process. Finally, it is difficult to see how Ockelford’s (2007) model of musical working melody, which postulates short term and long term bundles of information, could explain the relative role of LTM and STM in the processing of PIM compared to the processing of melodic contour. For Ockelford (2002, 2007), all aspects of music are processed by a general relational processor that processes both relationships between notes, and higher-order relationships between note relationships (‘zygons’). Ockelford’s (2007) model of musical working memory presumably does not predict any difference between the contribution of STM and LTM information to the processing of PIM compared with melodic contour, as both PIM and melodic contour are note relationships that thus should be processed similarly. Similarly, the poorly-specified module in the working memory model of Berz (1995) for processing music is little able to explain this difference between the contribution of LTM and STM to the processing of PIM and contour.

There are some caveats about the conclusions of this study due to the nature of the stimuli and procedure used, specifically to do with its generalisability to melodies and music in general. In particular, as Ockelford (2007) points out, this kind of experiment is metamusical, in that it uses rhythmically complex unaccompanied tonal folk melodies of 8 and 16 notes in length, rather than complex, complete musical works. It may be that the comparative contribution of STM and LTM processes to the salience of PIM and melodic contour is different to what is suggested by this experiment in
atonal melodies, accompanied melodies, isochronous melodies, or in shorter melodies (e.g., 4 notes long) or longer melodies (e.g., 30 notes long or longer). Another methodological issue with this study was the definition of PIM used; I followed Stevens and Latimer (1992) in defining steps as intervals of 3 or less semitones and leaps as intervals of 4 or more semitones. If the conventional definition of steps and leaps is correct in terms of how pitch is cognised (see Section 4.2.2.2), it may be that this has influenced the results of Experiments 1a and 1b, as it is possible that in some cases there were changes from small-leaps to big-leaps, and changes from big-leaps to small-leaps, rather than changes from steps to leaps and changes from leaps to steps. However, considering the finding in Experiment 1a that step-to-leap alterations were significantly more salient than leap-to-step alterations, it is likely that this methodological issue has simply reduced the effect size of this difference in salience and does not have a significant impact on the pattern of results.

Finally, it is unclear from Experiments 1a and 1b whether the redintegration process is using veridical expectancies or schematic expectancies to reassemble melodic traces. These experiments used several presentations of each of 16 melodies, and thus it is possible that, over the course of the experiment, participants developed veridical expectancies for each of the melodies, and may have used those veridical expectancies about the melodies to discriminate between them; it is additionally unclear whether veridical and schematic expectancies are completely independent at a neural level of analysis. Additionally, it is possible that participants are using information about the schematic expectancies of melodies to complete the task, being sensitive to the expectancy of the melodies based on statistical knowledge about the frequency of note relationships. Experiment 2 was designed to differentiate between these two possibilities, and determine the role of schematic expectancies and veridical expectancies in the discrimination of PIM in a melody discrimination task.
CHAPTER 7

Experiment 2: Discriminating PIM and Contour in Unfamiliar Melodies Where Veridical Expectations Do Not Facilitate Recognition
7.1 Introduction

Chapter 7 details Experiment 2, an experiment designed as a further investigation of the nature of the cognitive mechanisms underlying the salience of PIM. Experiment 2 was designed to further examine the role of melodic expectancies. In particular, Experiment 2 is designed to investigate whether the melodic expectancies contributing to the pattern of results in Experiment 1a and Experiment 1b are schematic or veridical. Experiment 2 was designed so that the veridical expectancies of participants were disrupted. In different melody pairs, contour and PIM changes occurred in the standard melody, as in Experiment 1b; however, in same melody pairs, participants heard (two) changed versions of melodies, unlike Experiment 1b. Thus, in Experiment 2, they did not develop veridical expectancies of the melodies, as the only time they heard the ‘original’ melody (i.e., the melody heard in ‘same’ pairs in Experiments 1a and 1b) was as the comparison melody in ‘different’ pairs. Experiment 2 elicited a floor effect, which makes interpretation difficult. However, the presence of a floor effect at least suggests that LTM knowledge of melodies affects the discrimination of melodies.

7.1.1 General Objectives of Experiment 2

As discussed in Section 6.4, the explanation of how PIM is processed by memory for melodies that was most consistent with the results of Experiments 1a and 1b was the theory that a redintegration process uses LTM expectancies to reassemble decayed traces. However, Experiments 1a and 1b did not determine the relative roles of schematic expectancies and veridical expectancies in this redintegration process. Schematic expectancies are expectancies about the relationship between musical events based on knowledge of music in general (Bharucha, 1994; Huron, 2006). An example of a schematic expectancy is expecting, with unfamiliar melodies, to hear a melody moving by steps more often than leaps (Schellenberg, 1997). In contrast, a veridical expectancy is an expectancy about a particular melody; for example, if a person is familiar with the popular standard “Over The Rainbow” (Arlen & Harburg,
1939), they will expect that the first two notes of the melody will feature a leap of an octave, despite that they do not expect this leap in melodies in general.

The way the redintegration process uses veridical expectancies may resemble the way the redintegration process in verbal working memory uses linguistic expectancy processes, resulting in the lexicality effect, that is, that words are remembered better than nonwords (see Section 4.3.3.2). In contrast, the way the redintegration process uses schematic expectancies may resemble the linguistic expectancy processes behind the word frequency effect, that is, that more common words are recalled or recognised more often than less common words (see Section 4.3.3.2).

Studies of redintegration involving word lists (e.g., Gathercole et al., 1999; Schweickert, 1993; Thorn, Gathercole, & Frankish, 2005) have shown that a number of different properties of phoneme strings, such as word frequency, lexicality, and lexical neighbourhood size, are used by the redintegration process to reassemble decayed traces; see Figure 7.1 for a model of the process proposed by Gathercole et al. (1999). Additionally, Thorn et al. (2005) argue that linguistic information is not only used in redintegration but in the initial activation of the trace; for example, traces of words that are high in frequency are more likely to be activated than words that are low in frequency. However, most researchers interested in redintegration (e.g., Thorn et al., 2005), have used word lists designed to minimise chunking, rather than, for example, grammatical sentences or syntactically acceptable melodies. Thus it is unclear from research into redintegration of word lists whether the same effects will be in operation in experiments with stimuli where chunking is probably not minimised, such as, for example, Irish and German folk melodies. However, assuming that the redintegration process in memory for melodies functions similarly to the process proposed by Gathercole et al. (1999), it is represented in Figure 7.2.
Figure 7.1. A model of the process of redintegration, adapted from Gathercole et al. (1999). Memory traces may be intact, degraded or lost. Attempts are made to reconstruct degraded traces using lexical and phonotactic processes.

Figure 7.2. A model of the possible process of redintegration in music. Memory traces may be intact, degraded or lost. Attempts are made to reconstruct degraded traces using veridical and schematic expectancies.

Though it appears that different forms of expectancy may play different roles in memory for melodies, Experiments 1a and 1b were not designed to differentiate between the roles played by schematic expectancies and veridical expectancies in the
redintegration process. As described in Section 6.2.2.4, each participant in the experiment heard each previously unfamiliar melody used in the experiment, or a variation thereof, 16 times. This was because melodies were presented in pairs, with equal amounts of same and different trials. Thus, after a reasonable number of these presentations, it is likely that participants had developed some veridical expectancies regarding melodies in the experiment. Therefore, as unfamiliar melodies became increasingly familiar over the course of the experiment, it is likely that the veridical expectancies of participants would have facilitated discrimination of melodies in Experiment 1a, and inhibited discrimination of melodies in Experiment 1b. The lexicality effect, which most resembles veridical expectancies, is one of the stronger effects of redintegration (Thorn et al., 2005). If the redintegration process works similarly in melodies as in word lists, then veridical expectancies, which appear to resemble the lexicality effect, are likely to have a strong effect on the results of Experiments 1a and 1b.

Thus, it is the object of Experiment 2 to differentiate between effects caused by a redintegration process using schematic expectancies and a redintegration process using veridical expectancies. Therefore, this experiment resembles Experiment 1b in that it uses the stimuli and paradigm of Experiment 1a, but reverses the order of different trials. The only additional difference between Experiment 2 and Experiment 1b is that, in same trials, the melody pairs, although identical aside from a key transposition, are examples of alteration melodies used in Experiments 1a and 1b (e.g., with a contour direction change compared to the original melody in those experiments). Thus, the only time in Experiment 2 where participants hear the standard melodies used in Experiment 1a are as comparison melodies in a different trial. In this experiment, although participants still hear 16 versions of each melody, they are hearing 3 versions of the contour alteration melodies, 3 versions of the leap-to-step alteration melodies, 3 versions of the step-to-leap alteration melodies, 3 versions of the PIM and contour alteration melodies and 4 versions of the original melody (i.e., as the comparison melody). In contrast, in Experiments 1a and 1b, participants heard the original melody 12 times, and each of the alterations once.

It is anticipated that Experiment 2 will test schematic expectancies by inhibiting the development of veridical expectancies about the melody; although participants hear
each melody 16 times, they only hear the original melody as a comparison melody in different trials. This means that participants should have less well-developed veridical expectancies of the melodies in comparison to their expectancies in Experiments 1a and 1b, and will consider the melodies to be veridically different. However, the schematic expectancies in this experiment will remain the same; different trials in Experiment 2 are identical to different trials in Experiment 1b. Thus, any difference in results may be ascribed to the influence of veridical expectancies.

However, it is unclear what effect further disrupting veridical expectancies will have on the already low accuracy rates of Experiment 1a. Disrupting veridical expectancies may increase accuracy in that veridical expectancies are not misleading participants into thinking that different trials are same trials. Alternatively, disrupting veridical expectancies could simply further confuse participants about the nature of a correct melody; this would lead to a floor effect. The theory assumed in this experiment is that results will resemble those in Experiment 1b. Thus, participants will be unable to discriminate between melodies based on alterations to PIM, but will be more accurate at discriminating between short melodies based on alterations to contour direction.

7.1.2 Design and Variables

In a 2 x 4 repeated measures design, participants completed a melody discrimination task. The independent variables were the length of the melody, and the kind of alteration to the melody; the dependent variables were the Hit Rate and False Alarm Rate.

7.1.3 Hypotheses

The hypotheses in this experiment are derived from the theory that if PIM is encoded by a redintegration process using schematic expectancies, then reversing the presentation order of trials and disrupting veridical expectancies of melodies used in this experiment will delete any effect of PIM. Thus, the hypotheses replicate those in Experiment 1b. Specifically:
(i) That Hit Rates in response to PIM alterations in both short and long melodies will not differ from False Alarm Rates.

(ii) That HR-FA Rates in response to simultaneous PIM and contour alterations will be more salient than those in response to PIM alterations, in both short and long melodies.

(iii) That HR-FA Rates in response to contour alterations will be higher in short melodies than in long melodies.

7.2 Method

7.2.1 Participants

In Experiment 2, it was considered unnecessary to differentiate between musically trained and untrained participants, considering the lack of a significant difference between levels of training in Experiment 1a. Participants were undergraduate psychology students who had no hearing difficulties, did not have absolute pitch, and did not speak a tonal language. Participants had not participated in Experiments 1a or 1b. Twenty-seven participants (21 females and 6 males) had a mean age of 24.63 years ($SD = 11.86$) and reported an average of 0.87 years of musical training ($SD = 1.56$); only two participants in this experiment had more than 5 years of musical training. Undergraduate psychology students received course credit for participation.

7.2.2 Materials

Materials used in Experiment 2 were identical to those used in Experiment 1a and Experiment 1b, with one exception. As in Experiments 1a and 1b, melodies used in this experiment were derived from Irish and German folk melodies, were either 8 or 16 notes long, and were in the time signature 4/4 at the tempo 120bpm. Additionally, as with Experiments 1a and 1b, some melodies had changes to melodic contour direction, increases in PIM, decreases in PIM or changes to both melodic contour direction and PIM; changes to implied harmony incidental to these melody changes
were avoided where possible. However, the standard melody in a melody pair in Experiment 2 was always either in the key of A major or E major, and the comparison melody in a melody pair was always in the converse key to the standard melody; that is, if the standard melody was in the key of A major, the comparison melody was in the key of E major, and vice versa. This was unlike Experiment 1a, where the standard melody of a melody pair was always in the key of C major, whereas the comparison melody was always transposed in comparison to either the key of A major or E major, and unlike Experiment 1b, where the standard melody of a melody pair was always either in the key of A major or E major, and the comparison melody was always in the key of C major. This change in methodology was designed to keep the stimuli used in Experiment 2 otherwise identical to the stimuli used in Experiments 1a and 1b.

7.2.3 Apparatus

The apparatus used in Experiment 2 was identical to that used in Experiments 1a and 1b, with two exceptions; firstly, an Edirol UA-25 soundcard was used in preference to the inbuilt soundcard on the Acer laptop, and secondly, Sennheiser HD-650 headphones were used. It was not anticipated that this upgrade in equipment would affect results.

7.2.4 Procedure

The procedure used in Experiment 2 was identical to that used in Experiments 1a and 1b – participants completed a melody discrimination task where they had to determine whether two transposed melodies were the same or different – with two exceptions. Firstly, as with Experiment 1b, the order of presentation was reversed in every trial compared with Experiment 1a; e.g., the comparison melody in a trial in Experiment 2 was the standard melody in the equivalent trial in Experiment 1a, whereas the standard melody in a trial in Experiment 2 was the comparison melody in the equivalent trial in Experiment 1a (see Figure 7.3). Secondly, each participant heard four ‘same’ trials for a particular melody – e.g., ‘The Flower of Magherally’ – in each
of Experiments 1a, 1b, and 2. However, unlike Experiments 1a and 1b, where the ‘same’ trials for a particular melody were all identical, using unaltered melodies, Experiment 2 had four different ‘same’ trials, each with a different alteration of the melody as both the standard and the comparison melody. That is, for each melody in Experiment 2, participants hear four ‘same’ trials, and each of those same trials uses a different alteration of the melody – e.g., one with a contour alteration, one with a PIM increase alteration, one with a PIM decrease alteration, and one with an alteration to both PIM and contour. It was thought that this particular alteration would disrupt veridical expectancies regarding the melodies that are built up during the experiment.

![Diagram](image)

*Figure 7.3.* The top of the figure shows the length of different phases of the experiment, whereas the bottom of the figure shows the format of a typical experimental trial; Experiment 2 differs from Experiment 1b only in the stimuli used in same trials.

### 7.3 Results

In order to establish whether participants were able to discriminate any of the melody alterations, 2-Way Analyses of Variance were run, comparing the Hit Rate of each melody alteration condition to the False Alarm Rate to same melody pairs using that particular melody alteration (i.e., melody pairs where both melodies have the same alteration). Additionally, as with Experiments 1a and 1b, because of errors in stimulus
preparation, participants’ responses to the 16-note melody “Éamonn An Chnuic” were omitted from the analysis. An alpha level of .05 was used for all statistical tests.

Figure 7.4. Hit Rates and False Alarm Rates to different melody alterations in Experiment 2 (n = 27), in short melodies, with error bars representing standard error of the mean; StL refers to a reversed-Step-to-Leap alteration, LtS refers to a reversed-Leap-to-Step alteration, CA refers to a Contour Alteration and CPIMA refers to a simultaneous alteration to contour and PIM.

The first hypothesis was that Hit Rates in response to PIM alterations in both short and long melodies would not differ from False Alarm Rates. This hypothesis was supported for long melodies. In long reversed-step-to-leap melodies, the Hit Rate ($M = .43$, $SD = .21$) was not significantly different from the False Alarm Rate ($M = .45$, $SD = .17$), $F(1,27) = 0.18$, $p = n.s.$ In long reversed-leap-to-step melodies, the Hit Rate ($M = .37$, $SD = .21$) was not significantly different from the False Alarm Rate ($M = .39$, $SD = .23$), $F(1,27) = 0.10$, $p = n.s.$ Thus, participants were not able to discriminate between melodies based on PIM in long melodies. This hypothesis was also supported for short-reversed-step-to-leap melodies, where the Hit Rate ($M = .33$, $SD = 0.21$) was not significantly different from the False Alarm Rate ($M = .39$, $SD = .23$).
.21), \(F(1,27) = 2.00, p = n.s.\) However, as can be seen in Figure 7.4, this hypothesis was not supported in short reversed-leap-to-step melodies. In particular, in short reversed-leap-to-step melodies, the Hit Rate (\(M = .37, SD = .21\)) was significantly greater than the False Alarm Rate (\(M = .25, SD = .18\)), \(F(1,27) = 9.13, p < .05, d = 0.60.\) Post-hoc 2-Way Analyses of Variance were run on the Hit Rates of the short-reversed-leap-to-step melodies compared to the other short melody alterations, and on the False Alarm Rates of the short reversed-leap-to-step melodies compared to the other short melody alterations, in order to determine whether this significant difference was due to increased Hit Rates or decreased False Alarm Rates. Post-hoc analyses discovered that there was no significant difference between Hit Rate across conditions, \(F(1,27) = 0.19, p = n.s.,\) but that there was a significant difference in False Alarm Rate across conditions, \(F(1,27) = 15.20, p < 0.05, d = 0.71.\) This suggests that the cause of the significant difference between Hit Rates and False Alarm Rates in this condition was the comparatively low False Alarm Rates to reversed-leap-to-step alterations in short melodies, rather than the Hit Rates.

The second hypothesis was that HR-FA Rates in response to simultaneous PIM and contour alterations would be more salient than those in response to PIM alterations, in both short and long melodies. As shown in Figure 7.4, in short contour and PIM alteration melodies, the Hit Rate (\(M = .41, SD = .16\)) was not significantly different to the False Alarm Rate (\(M = .41, SD = .31\)), \(F(1,27) = 0, p = n.s.\) Similarly, in long contour and PIM alteration melodies, the Hit Rate (\(M = .37, SD = .21\)) was not significantly different to the False Alarm Rate (\(M = .40, SD = .21\)), \(F(1,27) = 0.53, p = n.s.\) In summary, in both short and long melodies, there was no difference between the Hit Rate and the False Alarm Rate. Thus, melodies with alterations to both PIM and contour could not have been more salient than melodies with just alterations to PIM; neither was salient. Thus, this hypothesis was not supported.

The third hypothesis was that HR-FA Rates in response to contour alterations would be higher in short melodies than in long melodies. As shown in Figure 7.4, this was not the case. In short contour alteration melodies, the Hit Rate (\(M = .32, SD = .14\)) was not significantly different to the False Alarm Rate (\(M = .37, SD = .20\)), \(F(1,27) = 1.23, p = n.s.\) Similarly, in long contour alteration melodies, the Hit Rate (\(M = .46, SD = .20\)) was not significantly different to the False Alarm Rate (\(M = .47, SD = .16\),
$F(1,27) = 0.12, p = n.s.$ Thus, as neither short nor long contour alteration melodies had a Hit Rate significantly different to its False Alarm Rate, short contour alteration melodies were not accurately discriminated more often than long contour alteration melodies. Thus, this hypothesis could not be supported.

In summary, in all but one of the melody alteration conditions, there was no significant difference between the Hit Rate and the False Alarm Rate, which largely supports the first hypothesis, but does not support the second or third hypothesis.

Table 7.1. Hypotheses in Experiment 2 and whether they were supported.

<table>
<thead>
<tr>
<th>#</th>
<th>Hypothesis</th>
<th>Supported?</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>That Hit Rates in response to melodies with PIM alterations will not be higher than False Alarm Rates in either short or long melodies</td>
<td>Partially</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(null)</td>
</tr>
<tr>
<td>II</td>
<td>That HR-FA Rates in response to melodies with simultaneous PIM and contour alterations will be higher than in response to melodies with PIM alterations, in both short and long melodies.</td>
<td>No</td>
</tr>
<tr>
<td>III</td>
<td>That HR-FA Rates in response to melodies with contour alterations will be higher in short melodies than in long melodies.</td>
<td>No</td>
</tr>
</tbody>
</table>

7.4 Discussion

Experiment 2, in sum, showed a large floor effect; of the eight conditions in the experiment, the only one that showed a Hit Rate greater than the False Alarm Rate was the short reversed-leap-to-step melody alteration. This general floor effect was predicted for both reversed-leap-to-step and reversed-step-to-leap alterations in short and long melodies, thus supporting the first hypothesis. This general floor effect was also predicted for contour alterations and contour and PIM alterations in long melodies, but it was not predicted for the contour alterations or the contour and PIM alterations in short melodies; thus the second hypothesis, that alterations to both PIM and contour would be more salient than alterations to PIM in short and long melodies,
and the third hypothesis, that contour alterations would be more salient in short than in long melodies were not supported. The results of this experiment therefore did not support the general hypothesis that the results of Experiment 1a would be replicated. Instead, the results of this experiment suggest that, if the methodology of Experiment 2 successfully disrupted veridical expectancies, then veridical expectancies disrupt not only information about PIM but also information about melodic contour.

What then caused the results of this experiment? One reason for this general floor effect may be because this experiment did not successfully disrupt veridical expectancies. In Experiment 2, participants heard four different versions of a melody in the four different same trials that corresponded to a particular melody, one each with a contour alteration, PIM increase, PIM decrease and with a PIM and contour alteration. It was thought that this method would disrupt veridical expectancies, as participants never heard the original version of the melody, except as the comparison melody in a different trial. It may be, however, that this methodology did not prevent the formation of veridical expectancies; over the course of the experiment, participants would have heard four minor variations from the melody. Veridical expectancies may have developed, which may have thus made comparison melodies in different trials difficult. If veridical expectancies partially developed, these would make same trials difficult (Bartlett & Dowling, 1988). Participants in the experiment, who, because of the limits of working memory, have to reconstruct the standard melody in order to retain it in memory, may use veridical expectancies for this purpose. Especially considering the high False Alarm Rates in this experiment, these participants are likely to have perceived differences in the melodies where there were none; a contour alteration in the comparison melody, for example, may sound ‘different’ though it was also present in the standard melody.

Post-hoc analysis of the only condition where the Hit Rate was significantly greater than the False Alarm Rate, short reversed-leap-to-step melodies, supports this hypothesis. The analysis suggested that the Hit Rate being significantly greater than the False Alarm Rate was because of a low False Alarm Rate rather than because of a low Hit Rate. In short melodies in Experiment 1a, the mean HR-FA for this condition in Experiment 1a was 0.317, which was significantly less than the means from other conditions, which ranged from 0.435 to 0.602. Leap-to-step melodies are thus the
melodies most likely to be confused with the original melody. If this interpretation of
the results is correct, then it may be that the significantly lower False Alarm Rate in
response to leap-to-step melodies is because participants are not as misled by their
veridical expectancies of leap-to-step melodies in same trials.

The floor effect in Experiment 2 removed the salience of contour alterations and PIM
and contour alterations in short melodies; in contrast, the floor effect in Experiment
1b did not prevent these from being salient. This may cause problems for the theory
which was used to explain the results of Experiments 1a and 1b; this theory posited
that PIM is largely reliant on LTM information gained through a redintegration
process where contour is largely reliant on STM information gained through analysis
of perceptual information (e.g., the relational coding mechanism). Under that theory,
participants’ performance in those conditions more based on STM information should
not be affected by the disruption of veridical expectancies. This was not the case;
there was a floor effect in those conditions. There are two likely explanations of this
floor effect; the first is that participants responding to the contour alteration and PIM
and contour alteration conditions were more likely to respond correctly to different
trials in these conditions, but were also more likely to respond incorrectly to same
trials. The second explanation of this floor effect is that participants’ veridical
expectancies of these melodies were disrupted, making the task difficult even for
those conditions where participants should be more reliant on STM information. This
explanation suggests that, even though alterations to contour in short melodies were
more reliant on STM, they could still be affected by the redintegration process,
especially where participants were less confident about the veridical expectancies of
the melodies.

In conclusion, the general floor effect in Experiment 2 is problematic for the theory
suggested to explain the results of Experiments 1a and 1b. The floor effect may be
due to the failure of the experiment to properly disrupt veridical expectancies.
Alternatively, it may be due to an effect of the redintegration process on melodies
with alterations that should be more reliant on STM information. Future experiments
need to examine how participants respond to alterations to contour and/or PIM in
novel melodies, where melodies are not repeated within an experiment. Results from
these future experiments (that are beyond the scope of this thesis) would be greatly informative about the relative roles of schematic and veridical expectancies.
CHAPTER 8

Experiment 3: Discriminating Changes to Metre and Pulse in a Key Transposed Melodic Discrimination Task
8.1 Introduction

Chapter 8 details Experiment 3, an experiment designed to investigate the hypothesis, deduced from the model outlined in Chapter 5, that temporal information in melodies is processed by a relational coding mechanism. If so, temporal information in melodies should be discriminated in similar ways to how pitch information was discriminated in Experiments 1a and 1b (e.g., with manipulations of melody length, and transposition within pairs). As detailed in Section 8.4, the overall pattern of results in Experiment 3 was similar to those in Experiments 1a and 1b: firstly, changes to pulse and changes to metre were salient; secondly, short melodies were discriminated more accurately than long melodies, and thirdly, temporal changes were more salient in the comparison melody than in the standard melody. Thus, as detailed in Section 8.5, Experiment 3 suggests that temporal information in memory for melodies is processed in similar ways to that of pitch information.

8.1.1 General Objectives of Experiment 3

The purpose of Experiment 3 is to determine whether changes to metre and pulse are salient to listeners in a melody discrimination task where short and long tonal melodies have been transposed in key within melody pairs. There is little research on the role of time in memory for melodies, and no published research using a melody discrimination task has specifically looked at the role of metre and pulse in memory for melodies, despite their relational nature, or examined memory mechanisms that may be responsible. However, there is extensive research on how time – in music, and in general – is perceived. It is, however, unclear whether these general processes of time perception apply to memory for melodies. As such, this time perception research was tangential to the theoretical chapters that motivated the research project of this thesis and did not inform Experiments 1a, 1b, or 2. However, time perception research has informed Experiments 3, 4, 5a and 5b, and it is therefore now necessary to review the literature on the perception and cognition of time, and, if these processes operate
in memory for melodies, to suggest possible effects that these processes may have on the way that short term memory processes melodies.

8.1.2 The Properties of Time in Music

At the most basic level, sound is impossible without time. Time is the psychological framework for auditory events and temporal change defines the properties of auditory events (Handel, 1988). Time is the subject of intense philosophical debate. One view, for example, is that time does not exist of itself; instead, the observer intuits time (e.g., Kant, 1787). All that a person can perceive of time is the period of time in attention at any one instant; the rest is a product of memory and expectation. The perception of time is, therefore, something that a listener must actively construct. This has implications for research examining memory for melodies. If time is a framework that must be actively constructed, then neural mechanisms or processes must construct it. These mechanisms and processes may play a role in memory for melodies, as melodies are explicitly temporal constructions. Thus it is necessary to examine models of time perception for the implications they may have for memory for melodies.

8.1.3 Theories of the Perception of Time

The human perception of time is not limited to the perception of music, but is involved in a large variety of activities that require a correct sequencing and timing of events, ranging from successfully throwing a punch to correctly typing a sentence at a fast speed. Three broad families of theories about the perception of time that largely, and implicitly, focus on the perception of music, will be explored in this section: firstly, the beat-based model of Povel and colleagues (e.g., Povel, 1981; Povel & Essens, 1985); secondly, statistical models (e.g., Drake & Botte, 1993; Keele, Nicoletti, Ivry, & Pokorny, 1989; Monahan & Hirsh, 1990); and thirdly, dynamic models (Large & M. R. Jones, 1999; Large, Fink, & Kelso, 2002). The beat-based models and statistical models, although based on musical terminology, generally appear to be models of the perception of metamusical sequences, whereas Large and
M. R. Jones (1999) explicitly claim that their model is a model of time perception in general.

8.1.3.1 Beat-based theories of time perception

The beat-based model of Povel (e.g., Povel, 1981, 1984) is characterised by Large and M. R. Jones (1999) as a clock model, as listeners, according to this model, map temporal events onto a clock grid. In the first stage of processing, according to Povel (1981), the listener attempts to divide the sequence of temporal events into equal intervals. Once a sequence has been satisfactorily divided in this manner, and a beat has been established, listeners attempt to map further events onto a beat. In this mapping, they are constrained by the limitations of the clock grid into subdividing temporal events into ‘long’ and ‘short’ events with a 1:2 ratio.

Large and M. R. Jones (1999) argue that the beat-based model, although limited in other respects, can satisfactorily explain the perception of regular events at fixed tempos (e.g., Bharucha & Pryor, 1986; M. R. Jones & Yee, 1993). However, Large and M. R. Jones further argue that, in situations where tempo varies – for example, in musical performances where rubato is used – the beat-based model is unable to adjust for even minor variations in tempo. In contrast, many listeners do not even notice minor variations in tempo – they appear to re-orient or adapt effortlessly to changing tempo (e.g., Vos, van Assen, & Francaronek, 1998). Thus this model has problems explaining the perception of time in music. In a task in an experiment reported by Keele et al. (1989), participants had to respond indicating whether a sequence of seven tones contained unequal time intervals. The results showed that participants’ ability to detect unequal time intervals was equivalent whether there was only one note with an unequal time interval or whether the beat increased or decreased during the presentation of the seven notes. Keele et al. interpret this as being problematic for beat-based models, as the model of Povel (1981, 1984) presumably predicts that a beat changing to a different speed would be more noticeable than a beat with one temporal event that was slightly too long. Thus, beat-based models of perception appear to be inaccurate insofar as tempo variation is part of performance, but they may be accurate and parsimonious in situations where tempo variation does not occur.
8.1.3.2 Statistical theories of time perception

Statistical theories of time perception (e.g., Drake & Botte, 1993; Keele et al., 1989; Monahan & Hirsh, 1990) generally propose that time is perceived through the comparison of perceptual input with memory traces of arbitrary time intervals. For example, Drake and Botte (1993) propose the *multiple-look strategy*, which involves the creation of a memory trace that includes statistical information about the average duration of temporal events and statistical information about degree of dispersion of temporal events (i.e., how much variation there is between temporal events – how many long and how many short events?). This has the advantage over beat-based models in that it is able to make predictions about the relative salience of differences in irregular sequences of temporal events compared to regular sequences of temporal events (Large & M. R. Jones, 1999). However, the Drake and Botte (1993) model is less able to explain how listeners are able to perceive complex rhythmic structures, such as Latin or jazz rhythms. These rhythms are based on syncopation, wherein accents in the music are placed on off-beats in a way that subverts schematic expectations about rhythm in Western music in general, but which may not subvert schematic expectations about rhythm within those particular genres. A model of perception that uses a simple metric of long compared to short temporal events is thus unable to model the perception of syncopation, as syncopation would not be perceptible without listeners automatically comparing the placement of accents to something resembling a temporal grid. In comparison, despite its problems dealing with changes in tempo, the clock model – that listeners place complex rhythmic structures on a grid - is intuitive in regards to syncopation in a way that statistical theories, such as that of Drake and Botte (1993), are not.

8.1.3.3 Dynamic theories of time perception

Dynamic theories of time perception (e.g., M. R. Jones & Boltz, 1989; Large & M. R. Jones, 1999) posit the presence of neural oscillators that actively entrain to recurring stimuli in the environment in order to anticipate future events. Large and M. R. Jones (1999) argue that a dynamic theory of time perception is in some way a combination
of statistical and beat-based models of time perception; the process of attending constantly adjusts the speed of the oscillations, and the oscillations are used in a similar manner as the clock grid in terms of the organisation of sound. Jones and colleagues have argued that this dynamic attending process is crucial to various aspects of perception; for example, the emotional cues in the melodic phrasing of a singer or instrument, which is often based on the variation of tempo and rhythm (M. R. Jones & Boltz, 1989).

The Large and M. R. Jones (1999) model posits that, in perceiving timing, humans rely on internal attending rhythms modelled as mathematical equations representing oscillators. These oscillators entrain to match external rhythms, and generate expectations about what is to come. For example, Boltz & M. R. Jones (1986) found that metre was important to the structure of melody, and argued that the perception of metre was based on the adjustment of attending rhythms to fit the melody. The role of attention in Large and M. R. Jones’s model (1999) is to monitor fluctuations and changes in the rhythm and make appropriate changes to the attending rhythms, thus changing our musical expectations. A series of experiments by Jones and colleagues have tested predictions made by the dynamic attending model. For example, in an experiment conducted by M. R. Jones, Moynihan, MacKenzie and Puente (2002), participants were asked to judge the similarity of a critical pitch to a standard pitch within a series of tones. Participants were poorer at judging the similarity if the interonset interval (the amount of time between the tones) before the critical pitch differed from the expected interonset interval. That the variation of interonset intervals can affect judgements of pitch strongly suggest that participants’ attention to a task involving pitch is affected by the temporal placement of pitched tones. This provides support for oscillator models, in that it shows that attention is dependent on internal rhythms.

**8.1.3.4 Conclusions**

In terms of the models briefly outlined in Section 8.1.2, it is concluded that it is more likely that the results of Experiments 3 and 4, which use naturalistic stimuli with complex temporal information, rather than isochronous beeps, will be explained by
the models of Povel (1984) and Large and M. R. Jones (1999) rather than statistical models such as that of Drake and Botte (1993). Although the experiments detailed in this thesis use what are intended to be naturalistic stimuli, there is little or no tempo variation within the melodies, as they were derived from MIDI files on the KernScores database, and were largely quantized. Thus, it may be appropriate to base experimental hypotheses where possible on predictions made by the model of Povel (1981, 1984), especially for Experiment 3, as the limitations of the model – its inability to handle variations in tempo – does not apply, and its strength – its simplicity – gives it much utility. However, where there is tempo variation between melodies in the construction of experimental stimuli, as in Experiment 4 (see Chapter 9), the model of Large and M. R. Jones (1999) may make more appropriate predictions for experimental hypotheses. Regarding melodies without tempo variation, both theories essentially predict similar results, as the theories differ not on the existence of a temporal grid but rather on the dynamicity of the temporal grid. Where the temporal grid is fundamentally not particularly dynamic – for example, with simple folk melodies with little tempo variation, the temporal grid model has more utility, but where experiments involve tempo variation, the temporal grid model is less useful than the more complex Large and M. R. Jones (1999) model.

8.1.4 The relevance of general theories of time to theories of relational memory for melodies

As memory for melodies is, by necessity, memory for temporally varying stimuli, memory for melodies must retain information about the temporal aspects of a melody. Considering the relational nature of memory for melodies, it is especially likely to retain information about relationships between temporal events, such as metre and pulse. In a relatively complex non-isochronous melody such as those used in this experiment, the pulse and metre of the melody are not physical attributes of the music but instead must be inferred by the participant, based on information about the relationships between the temporal position and amplitude between notes. In this context, the pulse of a melody refers to the recurrent isochronous temporal intervals that underlie a melody; for example, in a melody in the time signature of 4/4 at the
tempo of 120 bpm, there is a pulse every 0.5 s. The pulse is inferred; a given pulse may not correspond with a temporal event, but there is an expectation that it will. In contrast, in this context, the metre of a melody refers to the relationships between accents of these pulses; in a metre some notes will be accented more than others in a recurrent way. For example, in a melody in the time signature of 4/4 at the tempo of 120 bpm, there is a strong accent on every fourth pulse. Thus, a pulse alteration occurs when the recurrent relationship between the temporal locations of pulses is altered; for example, a pulse alteration occurs when a note in a melody is lengthened to indicate that there was an IOI between pulses of 0.71 s rather than 0.5 s. Similarly, a metre alteration occurs when the recurrent relationship between the temporal locations of accented pulses is altered; for example, a metre alteration occurs if there is a note in the melody that is lengthened in such a way that it alters the recurrent accenting of notes; for example, if there is a note in the melody that is lengthened so that there was an IOI between pulses of 1 s rather than 0.5 s, then it could be interpreted by participants as a bar in the time signature 5/4 rather than 4/4, thus altering the metre, but not altering the pulse.
Figure 8.1. Visual representations of stereo WAV files corresponding to one of the short melodies used in Experiment 3, taken from the program Audacity 3.1 Beta. The numbers on the X axis across the top of the image represent length in seconds, while the numbers on the Y axis on the left side of the image represent loudness. The first stereo WAV file is the original melody, the second stereo WAV file is that melody with a pulse alteration and the third stereo WAV is that melody with a metre alteration.

A detailed analysis of research into the discrimination of temporal information in a melody discrimination task is contained in Sections 3.2.4 and Sections 3.2.4.1-3.2.4.6. However, as argued in Section 3.2.4.6, there has not yet been any research into memory for temporal information in melodies that has varied stimulus length or ISI; neither has any research into memory for temporal information in melodies yet has transposed melodies, either in key or in time. Thus, no available published research has yet systematically investigated the role of short- compared to long term memory processes in memory for temporal information in melodies, and no available published research has systematically forced participants to use relational temporal information in deciding whether the two melodies were the same or were different.
Because of this lack of research, it is unclear whether general time perception processes (e.g., Drake & Botte, 1993; Large & M. R. Jones, 1999; Povel, 1981) operate in memory for melodies, or whether temporal information in memory for melodies is the result of separate or partially separate processes unique to memory for melodies. These are empirical questions, and Experiments 3 and 4 investigate these questions further.

The model detailed in Chapter 5 posits that, in memory for melodies, under conditions of transposition, alterations to temporal information will be salient because they are encoded by the relational coding mechanism; long notes are accented in similar ways to notes where there are alterations to melodic contour (e.g., where a melody that had been rising begins to fall). However, because of the aforementioned lack of systematic research, it is an as yet unanswered empirical question as to whether this model is correct, or whether general time perception processes are responsible for the perception of temporal events in memory for melodies. In summary, the model detailed in Chapter 5 predicts that temporal length of a note will be more salient to participants than that note’s deviation from the temporal grid. However, if time perception processes apply to memory for melodies, then a note’s deviation from the temporal grid should be more salient than its temporal length.

8.2. Aim and Design

In Experiment 3, participants performing a melody discrimination task with short and long melodies transposed within pairs discriminated between melodies on the basis of alterations to pulse and metre. If memory for melodies uses generalised dynamic timing mechanisms, along the lines of Large & M. R. Jones (1999), results in experiments testing memory for melodies should be similar to those found in experiments testing general timing perception (e.g., pulse alterations should be more salient than metre alterations). However, if memory for melodies uses specific timing mechanisms specific to relational memory for melodies (e.g., the RCM), results are
likely to differ from those in experiments testing general timing perception (e.g., metre alterations should be more salient than pulse alterations).

Thus it may be useful to take an experimental paradigm from the time perception literature and alter it so that it better incorporates melodies. One timing experiment that may be appropriate for this task is that of Bharucha and Pryor (1986). Coming from a theoretical viewpoint similar to that of Povel (1984), and testing a model of time perception as a clock grid, Bharucha and Pryor (1986) studied the effects of disrupting the isochronous grid underlying rhythmic sequences by varying interonset intervals at various points in the rhythmic sequences. Participants completing a discrimination task in their experiment had to discriminate between a standard rhythmic stimulus and a comparison rhythmic stimulus transposed an octave higher. Two forms of temporal alterations could appear in either the standard and comparison stimuli. One (equivalent to a metre alteration condition in this experiment) varied an IOI in the stimulus so that it was double that of the normal stimulus, whereas the other varied an IOI in the stimulus so that it was less than double that of the normal stimulus, but that it disrupted the pulse (e.g., equivalent to the pulse alteration condition in this experiment). Participants in Bharucha and Pryor’s (1986) experiment were significantly better at detecting pulse alterations than metre alterations. Additionally, they were better at detecting differences in the comparison stimuli than they were at detecting differences when the rhythmic disruption were the standard stimuli – in other words, they were better at detecting the addition of a rhythmic anomaly than the deletion of a rhythmic anomaly.

If the experiment of Bharucha and Pryor (1986) was altered so that, instead of non-varying pitch, the rhythmic sequences in the experiment were instead melodies, the methodology would effectively be that of a melody discrimination task similar to that used in Experiment 1a in this thesis (see Chapter 6). Therefore, the aim of Experiment 3 was to investigate memory for temporal information in melodies by using a melody discrimination task similar to Experiment 1a with similar 8 and 16 note melodies. However, instead of varying the PIM and pitch contour of the melodies, as I did in Experiments 1a, 1b and 2, melodies in Experiment 3 were manipulated by lengthening notes within the melody, along the lines of Bharucha and Pryor (1986). The lengthened notes appeared in either the standard or the comparison stimuli, after
Bharucha and Pryor (1986), and the amount of lengthening varied so that the rhythm either still fitted into the metric grid of the melody, but altered the metre (i.e., the note is lengthened by a beat, changing the time signature of the bar in which the note is in from 4/4 to 5/4) or disrupted the pulse of the melody (i.e., the note is lengthened by 7/12s of a beat).

One objective of Experiment 3 was to determine whether general time perception processes (GTPP) play a role in memory for melodies, or whether memory for temporal information in melodies is due to a separate process such as the RCM. It should not surprise readers of this thesis that the hypotheses in Experiment 3 are based on the theory that the relational coding mechanism explicated in Chapter 5 is responsible for memory for temporal information in melodies. Because Bharucha and Pryor (1986) used such impoverished stimuli, with little melodic variation, it appears sensible to assume that participants in that experiment were using general time perception processes; Bharucha and Pryor thus appropriately explain their results in terms of the clock grid theory of Povel (1984). In contrast, in stimuli with melodic variation (e.g., melodies), it is possible that the RCM processes such melodies rather than GTPP. In Experiment 3 it is firstly predicted – whether or not GTPP or RCM is responsible – that note lengthenings will be salient to participants in the comparison melody in short melody pairs, regardless of the role of long term memory. Secondly, if GTPP is responsible, it is predicted that, in short melodies, lengthened notes that do not fit into the metric grid of the melody will be more salient than lengthened notes that do fit into the metric grid of the melody, even though lengthened notes that fit into the metric grid of the melody are temporally longer. In contrast, if REM is responsible, it is predicted that, in short melodies, lengthened notes that are temporally longer will be more salient.

A second objective was to determine the relative role of long term memory processes in memory for temporal information. Although empirical research is unclear on what effect might be had by LTM expectancies on memory for temporal information in melodies, both theories (i.e., GTPP and RCM) predict that temporal information will be more salient in short melodies than in long melodies. In contrast, a theory predicting that memory for metre and pulse is partly the result of a redintegration
process using LTM information predicts little difference between the salience of long and short melodies.

Regardless of whether GTPP or RCM is responsible, like Bharucha & Pryor (1986), and analogous to the results in Experiment 1a compared to Experiment 1b, it is predicted that the insertion of a lengthened note will be more easily detected by participants than the removal of a lengthened note.

The article published by Bharucha and Pryor (1986) does not mention whether participants were musically trained or not. Thus, it is difficult to discern what effect musical training might have on the pattern of results. Thus, it is predicted that results will largely follow those in Experiment 1a; temporal alterations will be significantly more salient to those with musical training than those without musical training, but that there will be no interactions between musical training and particular conditions in the experiment.

8.2.1 Design

In a 2 x 2 x 7 repeated measures design, participants completed a melody discrimination task. There were two groups; in one group participants had less than two years of musical training, whereas in the other group participants had more than five years of musical training. This was the between-groups independent variable. The within-groups independent variables were the length of melodies (short or long) and the kind of melody alteration pair (this variable had 7 levels; normal/metre alteration pair, normal/pulse alteration pair, metre alteration/normal pair, pulse alteration/normal pair, metre alteration/pulse alteration pair, pulse alteration/metre alteration pair, normal/contour alteration pair).

Dependent variables were the Hit Rate (correct “different” responses), False Alarm Rate (incorrect “different” responses), and the Hit Rate minus False Alarm Rate (the correct “different” responses minus the incorrect “different” responses). Where the hypotheses involved the overall salience of an independent variable, the Hit Rate was compared to the False Alarm Rate. Where the hypothesis involved the relative
accuracy of one level of an independent variable compared to another, the Hit Rate
minus False Alarm Rates in those conditions were compared.

### 8.2.2 Hypotheses

The hypotheses in this experiment were that:

(i) Hit Rates in response to both pulse and metre alterations in the comparison
melody in a pair of short melodies will be higher than False Alarm Rates
to short *same* melodies.

(ii) Hit Rate minus False Alarm Rates in response to both pulse and metre
alterations will be higher in comparison melodies than in standard
melodies.

(iii) Hit Rate minus False Alarm Rates in response to both pulse and metre
alterations will be higher in short melodies than in long melodies.

(iv) Hit Rate minus False Alarm Rates in response to alterations to the
comparison melody in short melody pairs will be higher with metre
alterations than with pulse alterations.

(v) Hit Rate minus False Alarm Rates in response to alterations to the
comparison melody in long melody pairs will be higher with metre
alterations than with pulse alterations.

(vi) Hit Rate minus False Alarm Rates in response to contour alterations in the
comparison melody will be higher in short melodies than in long melodies.

(vii) Hit Rate minus False Alarm Rates of participants with musical training in
response to temporal alterations will be higher than Hit Rate minus False
Alarm Rates of participants without musical training, and there will be no
interaction between the level of musical training and particular
experimental conditions.

### 8.3 Method
8.3.1 Participants

As in Experiment 1a, participants in the musically untrained group were undergraduate psychology students who reported less than two years of musical training, no hearing difficulties, no absolute pitch ability, and no speaking of a tonal language. The 20 participants (17 females and 3 males) in this group reported a mean age of 19.90 years ($SD = 3.02$) and an average of 0.73 years of musical training ($SD = 0.83$). Undergraduate psychology students received course credit for participation.

Like those in the musically untrained condition, participants in the musically trained group reported no hearing difficulties, no absolute pitch ability, and no speaking of a tonal language. Participants in this group reported at least 5 years of structured musical training. As with Experiment 1a, participants in this group were either undergraduate psychology students who received course credit, volunteers from the local community who received travel costs in return for participation, or postgraduate students studying at the University of Western Sydney. The 17 participants (11 females and 6 males) in this group reported a mean age of 23.82 years ($SD = 5.40$) and an average of 8.42 years of musical training ($SD = 6.21$).

8.3.2 Materials

The stimulus materials were 44.1 kHz 1411 kbps stereo WAV files that were converted from monophonic, unaccompanied MIDI files of four German folk melodies and four Irish folk melodies from the KernScores database (http://kern.ccarh.org/, 2001). These melodies were not used in Experiments 1a, 1b and 2. As in Experiment 1a, the melodies used in Experiment 3 were not isochronous but had an isochronous pulse, were strongly tonal, and were expected to conform to the schematic expectancies of most Western listeners. In a pre-test, each of the eight melodies used in this experiment were played to three listeners with over five years of musical training; no listener recognised any melody as a familiar melody. Thus these melodies were deemed unfamiliar to Australian participants. As in Experiment 1a, melodies in Experiment 3 were created by taking the final 8 or 16 notes of a melody from the KernScores database. In some melodies, the ending of the melody used
several repeated tonic notes; in this experiment, some of these tonic tones were deleted in some melodies to allow for greater manipulability of melodies. See Appendix D for notated transcriptions of each melody used in this experiment; the WAV files used are on the data CD attached to this thesis.

As in Experiment 1a, four melodies were 8 notes long (‘short melodies’); the other four melodies were 16 notes long (‘long melodies’). The rationale for this was the difference between results with long compared to short melodies found by Edworthy (1985a; see Section 3.2.1.3). As with Experiment 1a, all melodies were presented at a tempo of 120 beats per minute (bpm) in the time signature 4/4. Standard melodies in Experiment 3 were either in the key of C major or the key of F# major. Comparison melodies to standard melodies in C major were either in A major or E major; comparison melodies to standard melodies in F# major were either in Eb major or Bb major. Because of the focus on rhythm and metre in Experiment 3, it was decided that notes would be accented relative to each other in volume in order to simplify the task of determining the rhythm. Notes that were considered to land on the 1st beat of the bar were given the maximum MIDI velocity of 127. This usually approximately corresponded to a maximum level of -10 dB in the WAV file. Notes that were considered to land on the 3rd beat of the bar were given a velocity of 112, which usually approximately corresponded to a maximum level of -13 dB in the WAV file. Notes that were considered to land on either the 2nd or 4th beats of the bar were given a velocity of 96, which usually approximately corresponded to a maximum level of -16 dB in the WAV file, whereas notes that landed on off-beats were given a velocity of 80, which usually approximately corresponded to a maximum level of -19 dB in the WAV file. As in Experiment 1a, in a pre-test, each of the 8 melodies used in this experiment were played to three listeners with over five years of musical training; no listener recognised any melody as a familiar melody. Thus these melodies were deemed unfamiliar to Australian participants.

Following Bharucha & Pryor (1986), there were three types of variations to the temporal information in the melodies. Firstly, some melodies, the no difference (ND) melodies, retained the temporal information present in the original melodies. Secondly, some melodies, the metre alteration (MA) melodies, had temporal alterations where a note was lengthened for one metric beat, with further notes in the
melodies moved back a beat; in essence, this added a beat to the metre, changing the
time signature from 4/4 to 5/4. In a 120 bpm melody, adding a beat to the metre
lengthens the stimulus by 0.5 seconds. No intensity accents were changed. Thirdly,
some melodies had temporal alterations where a note was lengthened for 7/12ths of
one metric beat; in a 120bpm melody, adding 7/12\textsuperscript{th} of one metric beat lengthens the
stimulus by 0.29 seconds. These melodies, the pulse alteration (PA) melodies,
disrupted the pulse of the melody. The position of the temporal alteration within the
melody was counterbalanced across melodies so that the 8 and 16 note melodies had
similar numbers of temporal alterations at the start, middle and end of the melodies.
Additionally the position of the temporal alteration was counterbalanced across
melodies so that there are similar numbers of metre alteration melodies and pulse
alteration melodies with temporal alterations at the start, middle, and end of the
melodies.

Additionally, the alteration to the original melody could either be in the standard
melody or the comparison melody, following the methodology of Bharucha & Pryor
(1986). Using this methodology, Experiment 3 is the equivalent of Experiment 1a and
1b put together, using both normal and reversed presentation order within-trials.
Therefore, nine different pairs of temporal variations on the melodies were presented
to participants. Three were same trials: ND-ND, MA-MA, and PA-PA; whereas six
were different trials: ND-MA, ND-PA, ND-MA, MA-PA, PA-ND, and PA-MA.

Following Experiments 1a, 1b and 2, a contour change (CC) was present in some
trials. In these stimuli, one note in the melody was changed so that the direction of the
pitch interval between that note and both the note before and the note after it was
altered from up to down, or vice versa. For example, the melodic sequence F4 E4 F4
might be changed to F4 G4 F4, altering the direction of the melody from down-up to
up-down. There were no temporal alterations in these melodies. Following the finding
by Schubert and Stevens (2006) that musicians are sensitive to implied harmony in
melodic contour, all changes made to the stimuli to alter the contour preserved
implied harmony as far as possible. It should be noted that the contour change
melodies in this experiment were not of interest to the hypotheses underlying
Experiment 3. Instead, in Experiment 3, the presence of contour changes was thought
to encourage participants to listen to the stimuli as melodies rather than collections of
temporal intervals. Additionally, the results from the contour change conditions, if similar to those in Experiment 1a, suggests that participants are processing temporal information in this experiment in memory for melodies.

In post-experimental interviews, participants in Experiment 1a signalled that they were distracted by the monotony of the single flute timbre used in those experiments. In Experiment 3, two separate timbres were used to make the experiment less monotonous; these were an acoustic piano timbre (i.e., using samples from a grand piano), and an electric piano timbre (i.e., using samples from the Rhodes and Wurlitzer electric pianos common in the 1960s and 1970s). The choice of sampled piano timbres was because these were percussive timbres, being samples or synthesised emulations of an instrument using hammered strings. Thus, these timbres were considered more likely than flute timbres to emphasise the rhythm of the melodies.

8.3.3 Apparatus

The stimuli were manipulated using the software Propellerhead Reason 3.0 and were then converted to 44.1 kHz stereo WAV files. Stimuli were presented to participants through Sennheiser HD-650 headphones, using an Edirol UA-25 soundcard. The stimuli were presented to participants on an Acer Laptop, using the experimental software DMDX 3.1. Statistics were tabulated using Microsoft Excel XP, and were calculated using WinPsy2000.

8.3.4 Procedure

The experimenter began the experiment by giving the participant an information sheet and obtaining consent, according to the requirements of the University of Western Sydney Human Research Ethics Committee (see Appendix G for the information sheet and consent form). Participants then filled in a questionnaire that had questions about their age, gender, handedness, level of musical training, experience with languages other than English, and their possession of absolute pitch (see Appendix
G). The experimenter explained that all comparison melodies, even those that are otherwise the same, were key transpositions of the standard melodies, and explained that key transpositions thus did not count as different in this experiment. Using a Roland KF-90 Digital Piano, the experimenter then gave examples of transposition, and of same and different pairs of melodies using well-known nursery rhymes such as “Mary Had A Little Lamb” and “Twinkle Twinkle Little Star”. Before starting the experimental trials, participants were presented with twelve practice trials, half of which used an 8-note melody, and half of which used a 16-note melody. Melodies used in practice trials were based on a folk melody from the KernScores website database not used in the experimental trials (see Appendix D). In the practice trials, participants were given corrective feedback. No feedback was given in the experimental trials.

In each experimental trial, participants heard a pair of melodies, with an inter-stimulus interval (ISI) of one second. Participants were asked to press a button on the left side of a computer keyboard marked “diff” (the left shift key), immediately after they heard any difference between the pair of melodies, or to press a button on the right side computer keyboard marked “same” (the right shift key) if they heard no difference. There was an inter-trial interval of one second.

If each participant heard a trial corresponding to every possible stimulus pair, with equivalent amounts of same and different trials, the experimental session would be 190 minutes long. This was considered beyond the attention span of most adults, and four separate sets of stimuli were therefore created to shorten the experimental session for participants. These stimuli sets were identical except that a) the comparison melody in any one pair of melodies was transposed to the key of E major in one set and transposed to the key of A major in the other set, and b) the melody pair was presented in an acoustic piano timbre in one set and in an electric piano timbre in a second set. Thus for any particular melody pair, participants heard either a) a pair in acoustic piano timbre, with the standard melody in C major and the comparison melody transposed to A major, b) a pair in acoustic piano timbre, with the standard melody in F# major and the comparison melody transposed to Eb major, c) a pair in electric piano timbre, with the standard melody in C major and the comparison melody transposed to E major, c) a pair in electric piano timbre, with the standard
melody in F# major and the comparison melody transposed to Bb major. Participants were randomly assigned to one of the four stimulus sets. These stimuli sets were not treated as different in statistical analysis. Each participant completed one set of 112 experimental trials with a different randomised presentation order (see Figure 8.2). Over the course of the experiment, each participant heard each melody, or a variation upon that melody, 28 times. For each of the 8 melodies in the experiment, participants heard 14 pairs; 3 ND-ND pairs, 2 MA-MA pairs, 2 PA-PA pairs, 1 ND-CC pair, 1 ND-MA pair, 1 ND-PA pair, 1 MA-ND pair, 1 PA-ND pair, 1 MA-PA pair, and 1 PA-MA pair. The experiment took 50 minutes to complete. There were equal proportions of same trials and different trials, but participants were given no information about the proportion of same trials compared to different trials.

![Diagram](image)

*Figure 8.2.* The top of the figure shows the duration of different phases of the experiment, whereas the bottom of the figure shows the format of a typical experimental trial. Alterations may be in either the standard or the comparison melody

### 8.4 Results

As with Experiments 1a, 1b, and 2, Experiment 3 was analysed using planned hypothesis testing in WinPsy2000. Where results related to the comparison of Hit rate
to False Alarm Rate in order to determine whether a particular condition was salient, a 2x2x7 Analysis of Variance was performed, with the three main variables being the musical training of the participants, the length of melodies, and the Hit Rates and False Alarm Rates to particular melody pairs. Where results related to the comparison of Hit Rate minus False Alarm Rates in different conditions, in order to determine whether a particular condition was more salient than another, a 2x2x7 Analysis of Variance was performed on the data, with the three main variables being musical training, length of melodies, and Hit Rate minus False Alarm Rate. An alpha level of .05 was used for all statistical tests.

![Graph showing mean hit rate minus false alarm rate for different melody alteration types](image)

*Figure 8.3.* Mean Hit Rate minus False Alarm Rate to long and short melodies, with error bars representing standard error of the mean. ND-CC indicates a contour change in the comparison melody; ND-MA indicates a metre alteration in the comparison melody; ND-PA indicates a pulse alteration in the comparison melody; MA-ND indicates a metre alteration in the standard melody; PA-ND indicates a pulse alteration in the comparison melody; MA-PA indicates a metre alteration in the standard melody and a pulse alteration in the comparison melody; PA-MA indicates a pulse alteration in the standard melody and a metre alteration in the comparison melody.

The first hypothesis in this experiment, that both metre and pulse alterations would be salient to participants when in the comparison melody in a pair of short melodies, was supported. The Hit Rate from participants discriminating metre alterations in the
comparison melody ($M = 0.75, SD = 0.24$) was significantly greater than the False Alarm Rate ($M = 0.07, SD = 0.09$), $F(1,35) = 222.15, p < .05, d = 3.21$. Similarly, the Hit Rate from participants discriminating pulse alterations in the comparison melody ($M = 0.71, SD = 0.25$) was significantly greater than the False Alarm Rate ($M = 0.07, SD = 0.09$), $F(1,35) = 194.03, p < .05, d = 2.99$. Therefore, both metre and pulse alterations were salient to participants when in the comparison melody in a pair of short melodies.

The second hypothesis in this experiment, that both metre and pulse alterations would be more salient to participants in the comparison melody than in the standard melody, was supported. In short melodies, as can be seen in Figure 8.3, metre alterations were more salient in the comparison melody ($M = 0.67, SD = 0.27$) than in the standard melody ($M = 0.41, SD = 0.30$), $F(1,35) = 20.25, p < .05, d = 0.91$. Similarly, in short melodies, pulse alterations were more salient in the comparison melody ($M = 0.62, SD = 0.27$) than in the standard melody ($M = 0.36, SD = 0.33$), $F(1,35) = 13.72, p < .05, d = 0.92$. Again, in long melodies, metre alterations were more salient in the comparison melody ($M = 0.38, SD = 0.30$) than in the standard melody ($M = 0.02, SD = 0.36$), $F(1,35) = 26.03, p < .05, d = 1.24$. Finally, in long melodies, pulse alterations were more salient in the comparison melody ($M = 0.48, SD = 0.27$) than in the standard melody ($M = 0.04, SD = 0.38$), $F(1,35) = 42.14, p < .05, d = 1.54$. Thus, the hypothesis was supported for both metre and pulse alterations in both short and long melodies.

As can be seen in Figure 8.3, the third hypothesis, that both metre and pulse alterations in the comparison melody would be more salient to participants in short melodies than in long melodies, was supported. Where there was a metre alteration in the comparison melody, this was more salient in short melodies ($M = 0.67, SD = 0.27$) than in long melodies ($M = 0.38, SD = 0.30$), $F(1,35) = 20.92, p < .05, d = 1.03$. Similarly, where there was a pulse alteration in the comparison melody, this was more salient in short melodies ($M = 0.62, SD = 0.27$) than in long melodies ($M = 0.48, SD = 0.27$), $F(1,35) = 5.560, p < .05, d = 0.48$. Thus, this hypothesis was supported for both metre and pulse alterations in the comparison melody.
The fourth hypothesis, that short melodies with a metre alteration to the comparison melody would be more salient than short melodies with a pulse alteration to the comparison melody, was not supported. As can be seen in Figure 8.3, metre alterations to the comparison melody \( M = 0.67, SD = 0.27 \) were not significantly more salient than pulse alterations to the comparison melody \( M = 0.62, SD = 0.27 \) in short melodies, \( F(1,35) = 1.26, p = n.s. \). Instead, the null hypothesis, that there was no difference between metre and pulse alterations to the comparison melody in short melodies, failed to be rejected.

The fifth hypothesis was that long melodies with a pulse alteration to the comparison melody would be more salient than long melodies with a metre alteration to the comparison melody. Pulse alterations to the comparison melody \( M = 0.48, SD = 0.27 \) were indeed more salient than metre alterations to the comparison melody \( M = 0.37, SD = 0.30 \) in long melodies, \( F(1,35) = 6.006, p < .05, d = 0.37 \). Thus, the fifth hypothesis was supported.

The sixth hypothesis was that, as in Experiments 1a and 1b, changes to melodic contour in the comparison melody will be more salient in short melodies than in long melodies. Melodic contour alterations in the comparison melody in short melodies \( M = 0.60, SD = 0.28 \) were more salient than melodic contour alterations in the comparison melody in long melodies \( M = 0.35, SD = 0.29 \), \( F(1,35) = 18.39, p < .05, d = 0.91 \). Thus the sixth hypothesis was supported.

The seventh hypothesis was that participants with musical training would more accurately complete the task than participants without musical training, with no interactions between training and particular hypotheses. There was an overall effect of musical training, with the melody alterations more salient to participants with musical training \( M = .36, SD = 0.39 \) than participants without musical training \( M = 0.25, SD = 0.36 \), \( F(1,35) = 6.74, p < .05, d = 0.39 \). However, despite this overall effect, there was no significant interaction between musical training and melody alteration type in any of the comparisons made in this experiment, as can be seen in Table 8.1; only \( F \) values above 4.121 would be significant at an alpha level of .05. Thus the hypothesis was supported; participants with musical training were significantly better at the task, but did not have a dramatically different pattern of results.

203
Table 8.1. The F values for the interactions between musical training and melody alteration type for the statistical analyses discussed in section 8.4.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>F value for interaction between training and melody alteration type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short vs Long Contour Alteration</td>
<td>0.10</td>
</tr>
<tr>
<td>Short vs Long Comparison Melody with Metre Alteration</td>
<td>0.04</td>
</tr>
<tr>
<td>Short vs Long Comparison Melody with Pulse Alteration</td>
<td>0.14</td>
</tr>
<tr>
<td>Pulse vs Metre Alterations in Short Comparison Melody</td>
<td>1.261</td>
</tr>
<tr>
<td>Pulse vs Metre Alterations in Long Comparison Melody</td>
<td>0.85</td>
</tr>
<tr>
<td>Pulse Alteration in Standard vs Comparison Melody in Short Melodies</td>
<td>0.06</td>
</tr>
<tr>
<td>Metre Alteration in Standard vs Comparison Melody in Short Melodies</td>
<td>1.27</td>
</tr>
<tr>
<td>Pulse Alteration in Standard vs Comparison Melody in Long Melodies</td>
<td>0.00</td>
</tr>
<tr>
<td>Metre Alteration in Standard vs Comparison Melody in Long Melodies</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Table 8.2. Hypotheses in Experiment 3, and whether they were supported.

<table>
<thead>
<tr>
<th>#</th>
<th>Hypothesis</th>
<th>Supported?</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>Hit Rates in response to both pulse and metre alterations in the comparison melody in a pair of short melodies will be higher than the False Alarm Rates to short melodies</td>
<td>Yes</td>
</tr>
<tr>
<td>ii</td>
<td>Hit Rate Minus False Alarm Rates in response to both pulse and metre alterations will be higher in comparison melodies than in standard melodies.</td>
<td>Yes</td>
</tr>
<tr>
<td>iii</td>
<td>Hit Rate Minus False Alarm Rates in response to both pulse and ...</td>
<td>Yes</td>
</tr>
</tbody>
</table>
metre alterations will be higher in short melodies than in long melodies.

iv Hit Rate Minus False Alarm Rates in response to alterations to the comparison melody in short melody pairs will be higher with metre alterations than with pulse alterations.

v Hit Rate Minus False Alarm Rates in response to alterations to the comparison melody in long melody pairs will be higher with pulse alterations than with metre alterations.

vi Hit Rate Minus False Alarm Rates in response to contour alterations in the comparison melody will be higher in short melodies than in long melodies.

vii Hit Rate Minus False Alarm Rates of participants with musical training in response to temporal alterations will be higher than Hit Rate Minus False Alarm Rates of participants without musical training, and there will be no interaction between the level of musical training and particular experimental conditions.

---

8.5 Discussion

The results of Experiment 3, firstly, suggest that memory for temporal information in melodies is processed in fundamentally similar ways to memory for pitch information and, in particular, memory for melodic contour. As with PIM and melodic contour, both pulse and metre alterations are salient to participants in short melodies, with hit rates significantly greater than False Alarm Rates. As with PIM and melodic contour, both pulse and metre alterations are more salient in the comparison melody than in the standard melody. As with melodic contour, short melodies with either pulse or metre alterations are more salient than the equivalent long melodies, as reflected in HR-FA rates. In the condition where there was a alteration to pitch, the melodic contour
alteration condition, Experiment 3 had the same pattern of results as in Experiment 1a; this similarity suggests that participants were not using dramatically different strategies to complete the task in Experiment 3 compared to Experiment 1a.

That short melodies with either pulse and metre alterations were significantly more salient than long melodies with either pulse and metre alterations suggests that temporal information is not reliant on the redintegrative process posited in Chapter 5. In Experiments 1a and 1b, the pattern of results suggested that PIM was reliant on LTM information; for example, there was little difference between the salience of PIM in short melodies compared to long melodies in Experiment 1a, and the reversed within-pair order in Experiment 1b removed any effect of PIM. In contrast, both pulse and metre alterations, when in the standard melody in short melody pairs, were still salient (means of 0.36 and 0.41, respectively). Similarly, both kinds of disruptions were more salient in short melodies than in long melodies. Thus, it appears from this experiment that neither pulse nor metre alterations are heavily reliant on LTM information. These results suggest that memory for temporal information in melodies is subserved by short term or perceptual mechanisms; whether metre or pulse was altered, participants were better at detecting alterations in short melodies and were better at detecting them in comparison melodies.

However, it is unclear from Experiment 3 as to whether general time perception processes or the relational coding mechanism was responsible for memory for temporal information in melodies. There was no difference in the salience of pulse alterations compared to metre alterations in the comparison melody of short melody pairs. In long melodies, however, there was a small effect of pulse alterations being more salient than metre alterations in comparison melodies in long melody pairs. This effect is problematic for the argument that a temporal grid mechanism such as that posited by Povel (1984) could be responsible for the encoding of temporal information in memory for melodies; such a model predicts that pulse alterations would be more salient than metre alterations in short melodies. Although such effects are found when simple beeps are used as stimuli (e.g., Bharucha & Pryor, 1986), the present experiment found no difference in short melodies. Similarly, this lack of a difference in salience is problematic for the relational coding mechanism hypothesis, as that hypothesis predicts that metre alterations would be more salient than pulse
alterations. The present experiment is therefore unable to determine whether general time perception processes or a relational coding mechanism play a role in memory for temporal information in melodies.

As neither theory accurately predicted the lack of a significant difference between metre alterations and pulse alterations in the comparison melody of short melody pairs, it is difficult to interpret the results without further empirical investigation. One possible interpretation is that, in short melodies, melodies were sufficiently short that the conversion of temporal information into relational form was unnecessary, or less important; thus participants used absolute temporal information to complete the task, and may have used different processes using temporal length and temporal grid deviation in order to discriminate between melodies. In contrast, when presented with long melodies, participants by necessity had to chunk, and used pulse information to do this more effectively. This led to an increase in comparative salience of pulse compared to metre. A second explanation is that, although LTM effects do not appear to have had much of an effect in the task used in this experiment, redintegrated memory traces may be more clearly different from melodies with a pulse alteration than with a metre alteration. One final explanation is that, for the comparison of pulse alterations to metre alterations in the comparison melody of short melody pairs, the experiment did not rule out the possibility of a significant difference; the upper limit of the 95% confidence interval for that comparison had a $d$ value of 0.29, which indicates that a small effect in the intended direction (e.g., that pulse alterations are more salient than metre alterations) is not ruled out by this experiment, though it has been shown to be unlikely. More statistically powerful replications of this experiment are necessary in the future to determine whether this alternative explanation of the results is the case.

There are, however, some limitations to what Experiment 3 can say about memory for temporal information in melodies. Firstly, the design of Experiment 3 did not force participants to encode the melodies as relational information. Although Experiment 3 used transposition in key, it did not use transposition in tempo. Thus, it is possible that participants simply ignored pitch information in this experiment, and completed the experiment using absolute sensory temporal information. However, the similarity between results in the contour change conditions of Experiment 3 and Experiment 1a
suggests that pitch information was not simply ignored. Experiments that have tested participants’ ability to detect alterations to melodic contour and have manipulated transposition find that participants are better at the task when there is no transposition in a melody pair (e.g., Bartlett & Dowling, 1980; Peretz, 1990). Thus, short term memory for melodies appears to be able to use absolute information in addition to relational information in order to discriminate between melodies. If, as Experiment 3 suggests, that memory for temporal information follows similar patterns to memory for melodic contour, memory for temporal information is likely to be able to use both absolute and relational information when appropriate. Experiment 4 will thus transpose melodies in tempo in order to force participants to use relational information in completing the task. This will test the relative roles of relational and absolute information.

Another methodological issue for Experiment 3 is that the experimental conditions used variations of only eight melodies. Thus, in a particular experimental trial, each participant would hear each melody 28 times. Thus, especially considering the results of Experiment 2, in which a floor effect was found when expectancies were not conducive to correctly discriminating between melodies, it may be that participants are using LTM expectancies to help them complete the task in this experiment. It should be pointed out, firstly, that the randomisation of trials in Experiment 3, wherein each participant received a different random order of trials, makes it unlikely that this disruptive effect had differential effects on one condition compared to another. Secondly, the use of repetition of melodies in Experiment 3 was useful for controlling for the possible effects of particular melodies, and the way they may interact with different rhythmic alterations. Additionally, the repetition of melodies made Experiment 3 comparable to Experiments 1a, 1b and 2, as these experiments largely use similar methodology, similar melodies, and similar samples. This added control and comparability was considered more important in designing these experiments than the effect of veridical expectancies. However, with these caveats, it would be beneficial for future research to modify the method of Experiment 3 so that each melody was only heard once within any particular experiment.

A further limitation of Experiment 3 was that it was difficult to determine whether the pulse alterations used in this experiment were of equivalent salience to the metre
alterations. This experiment used a single kind of pulse alteration (e.g., lengthening notes by 7/12s of a beat) and a single kind of metre alteration (e.g., lengthening notes by 1 beat), and it may be that these particular alterations were not representative of pulse alterations or metre alterations overall; it is possible that a different effect may be found with pulse alterations where notes were lengthened by 10/12s of a beat, for example. However, resolving whether the particular alterations used were representative of pulse and metre alterations is an empirical question, and future research should investigate whether the effects found in the present experiment were the result of the particular note lengthenings used, or whether they are representative of pulse and metre alterations in general.

In summary, Experiment 3 suggests that temporal alterations – whether metre alterations or pulse alterations – are salient to both musically trained and participants without musical training under conditions of key transposition within-pairs. It additionally suggests that such alterations show the characteristics of being encoded by perceptual mechanisms such as the relational coding mechanism or general time perception processes. Firstly, both alterations are more salient in short melodies than in long melodies. Secondly, both alterations are more salient in the comparison melody than in the standard melody, though also salient in the standard melody. However, Experiment 3 has not determined what role general time perception processes play in memory for melodies as opposed to the relational coding mechanism, and this may be because the stimuli and design of Experiment 3 did not require that participants use relational information to correctly complete the experiment. However, participants in Experiment 4 will have to use relational information to correctly complete the experiment, as Experiment will use the method of Experiment 3, but with transposition in tempo instead of key.
CHAPTER 9

Experiment 4: Discriminating Changes to Metre and Pulse in a Tempo Transposed Melodic Discrimination Task
9.1 Introduction

Chapter 9 details Experiment 4, an experiment designed to further investigate the hypothesis, derived from the model in Chapter 5, that temporal information in memory for melodies is processed by a relational coding mechanism. Experiment 4, as detailed in Section 9.2, was similar to Experiment 3 except that melodies were transposed in tempo rather than transposed in pitch; this forced participants to encode relationally in order to accurately discriminate melodies. Results, as detailed in Section 9.3, were generally similar to those in Experiment 3, which suggests that people use relational encoding to discriminate temporal information in melodies. However, notably, metre alterations were more salient than pulse alterations in short melodies, and there was a trend towards pulse alterations being more salient than metre alterations in long melodies, suggesting that pulse alterations may be more reliant on LTM processing. Thus, as detailed in Section 9.4, Experiment 4 suggests that memory for temporal information in melodies is processed in similar ways to pitch, and specifically that temporal information is encoded relationally.

9.1.1 General Objectives of Experiment 4

The purpose of Experiment 4 was to determine the extent to which the effects found in Experiment 3 were due to the relational coding mechanism, and the extent to which those effects were due to general time perception processes (e.g., Povel, 1984). Apart from changes to the melodies (i.e., pulse or metre alterations), in Experiment 3, the two melodies within a pair contained identical temporal information, with temporal events of equal duration and tempo. The design of stimuli in Experiment 3 meant that participants were not forced to encode rhythm relationally in order to discriminate between melodies, although they were forced to encode pitch relationally. The model detailed in Chapter 5 argues that a relational coding mechanism is largely responsible for encoding musical features such as melodic contour for the use of memory for
melodies. To test the model it is therefore necessary to design a task that forces participants to encode rhythm relationally in order to discriminate between melodies.

In Experiment 4, the melodies within any pair in a trial were transposed in tempo. This tempo transposition alters the absolute IOIs of temporal events, but does not alter the temporal relations (e.g., short and long) between events. Thus, in order to discriminate between melodies on the basis of changes to metre (e.g., lengthening a note by one beat) or pulse (e.g., lengthening a note so that it disrupts the temporal grid) in Experiment 4, participants must use relational coding. Thus, Experiment 4 replicated Experiment 3 with one major alteration; where, in Experiment 3, melodies within pairs were transposed in key but not tempo, in Experiment 4, melodies within pairs were transposed in tempo but not key.

9.1.2 Pilot Experiment to Determine Suitable Tempo

To establish suitable tempo transpositions for Experiment 4, a pilot experiment was conducted. It was considered that tempo changes at the point of a just noticeable difference would be most appropriate for Experiment 4. If the changes in tempo were less than noticeable, the argument that participants must encode temporal information relationally would be weaker; similarly, if the changes in tempo were large, the change in tempo might be overly distracting, especially with unfamiliar melodies such as those used in this experiment. In the pilot experiment, four participants with musical training and four participants without musical training were recruited from graduate students studying at MARCS Auditory Laboratories at the University of Western Sydney. Participants were asked to judge whether a pair of tonal, rhythmically complex, eight-note melodies (see Figure 9.1 for notation of the melody) were at the same tempo. Trial order was randomised. The standard melody was set at a rate of either 120 beats per minute (bpm) or 130bpm. Comparison melodies were either at the same tempo, or were 2, 5, 10, 20, or 45 bpm faster or slower than the standard melody. For example, when the standard melody was at the tempo of 120bpm, participants heard comparison melodies at the tempos of 75bpm, 100bpm, 110bpm, 115bpm, 118bpm, 120bpm, 122bpm, 125bpm, 130bpm, 140bpm, and 165bpm. Changes of 2, 5, 10, 20, and 45 bpm were chosen because the typical
A discernible tempo change is considered to be between 7.5-15% of the original (e.g., at 120bpm, a discernible tempo increase would be between 129bpm and 138bpm; Fraisse, 1982). Results, collapsed across participants, are shown in Table 9.1. As can be seen from the data, participants could not discriminate changes of 2bpm, and were poor at discriminating changes of 5bpm. Changes of 10bpm were discriminated most of the time, whereas changes of 20bpm or 45bpm were always discriminated. Therefore, a tempo change of about 10bpm was considered to be appropriate for this experiment, as it was closest to the point of a just-noticeable difference, and was noticeable enough for participants to discriminate it from the original, but not so great that it might distract or be overly obvious.

![Image](image.png)

*Figure 9.1. The excerpt from the folk melody “Runkelstube” which was used as stimuli in the Pilot Experiment.*

<table>
<thead>
<tr>
<th>Amount of Tempo Change (% increase at 120bpm)</th>
<th>2bpm (1.6%)</th>
<th>5bpm (4.2%)</th>
<th>10bpm (8.3%)</th>
<th>20bpm (16.6%)</th>
<th>45bpm (37.5%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR-FA rate</td>
<td>-0.07</td>
<td>0.18</td>
<td>0.56</td>
<td>0.78</td>
<td>0.78</td>
</tr>
</tbody>
</table>

### 9.1.3 Rationale and Description of Experiment 4

The method of tempo transposition used in Experiment 4 followed the method of key transposition used in Experiments 1a and 1b. In Experiment 4, the standard melody was played at 120bpm, whereas the comparison melody was played faster, at 130bpm,

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9 At 20bpm and 45bpm, participants recorded a Hit Rate of 1.
or slower, at 112bpm. The decision to include a larger change in bpm from the original in the fast melodies than in the short melodies was motivated by research by Wang (1984), who found that participants more readily discriminated decreases in tempo than increases in tempo. This tempo transposition is expected to be informative about the nature of the relational encoding of pitch in memory for melodies. The experiment additionally had some minor methodological changes. Instead of sampling both those with and without musical training, only those without musical training were recruited; in earlier experiments, there appeared to be little difference between the response patterns of those with musical training compared to those without musical training, beyond a general improvement in the discrimination accuracy of those with musical training. Additionally, because participants were generally poor at detecting alterations when the standard melody in a pair has a pulse alteration and the comparison melody has a metre alteration, or vice versa, these pairs were not included in Experiment 4. Similarly, to shorten the experiment, contour change melodies were not used as stimuli.

In Experiment 4, it was expected that results would be similar to those of Experiment 3, under the assumption that participants predominantly use the relational coding mechanism to encode temporal information in memory for melodies; if participants do not usually use a relational coding mechanism, then they will have a dramatically different pattern of response when forced to use relational encoding in order to discriminate between melodies. Thus, it was expected that both metre and pulse alterations would be salient in both the comparison melody or the standard melody of short melodies, more salient in the comparison melody of short melodies, and more salient in short melodies than long melodies. Additionally, it was expected that pulse alterations would be more salient than metre alterations in the comparison melody of long melodies, but that there would be no difference in short melodies.

### 9.1.4 Design

In a 2 x 4 repeated measures design, participants completed a melody discrimination task. The within-groups independent variables were the length of melodies (short or long) and the kind of melody alteration pair (normal/metric alteration pair,
normal/nonmetric alteration pair, metric alteration/normal pair, and nonmetric alteration/normal pair).

Independent variables were Hit Rate, False Alarm Rate, and the Hit Rate minus False Alarm Rate. Where the hypotheses involved the overall accuracy of a condition, the Hit Rate was compared to the False Alarm Rate. Where the hypothesis involved the relative accuracy of one condition compared to another, the Hit Rate minus False Alarm Rates to those conditions were compared.

### 9.1.5 Hypotheses

The hypotheses in this experiment were that:

(i) Hit Rates in response to both metre and pulse alterations when in the comparison melody in a pair of short melodies will be greater than False Alarm Rates to short melodies.

(ii) Hit Rates in response to both metre and pulse alterations when in the standard melody in a pair of short melodies will be greater than the False Alarm Rates to short melodies.

(iii) Hit Rate minus False Alarm Rates in response to both metre and pulse alterations in short melodies will be greater when the alteration is in the comparison melody than when the alteration is in the standard melody.

(iv) Hit Rate minus False Alarm Rates in response to both metre and pulse alterations in short melodies will be greater when the alteration is in short melodies than when the alteration is in long melodies.

(v) Hit Rate minus False Alarm Rates in response to alterations in the comparison melody of short melodies will not differ based on whether those alterations are to pulse or are to metre.

(vi) Hit Rate minus False Alarm Rates in response to alterations in the comparison melody of long melodies will be greater when those alterations are to metre than when they are to pulse.
9.2 Method

9.2.1 Participants

As in Experiments 1b and 2, participants were undergraduate psychology students who reported less than two years of musical training, no hearing difficulties, and no absolute pitch ability, and who reported that they had no experience speaking a tonal language. Participants in Experiment 4 had not participated in Experiment 3. The 20 participants (9 females and 11 males) had a mean age of 28.90 years ($SD = 13.61$) and reported an average of 0.18 years of musical training ($SD = 0.46$). Undergraduate psychology students received course credit for participation.

9.2.2 Materials

The stimulus materials used in Experiment 4 were generally identical to those used in Experiment 3 – that is, melodies were the same 8- and 16-note-long unfamiliar tonal folk melodies as used in Experiment 3 (see Appendix D for notated examples of the melodies used) and the same metre alterations and pulse alterations were made to these melodies in identical metric and serial positions. However, although the stimulus materials were generally identical, there were some differences.

Firstly, where all melodies were presented at a tempo of 120bpm, in the time signature 4/4, Experiment 4 varied the tempi of melodies. All standard melodies in Experiment 4 were at the tempo of 120bpm; however, comparison melodies in Experiment 4 were either at the tempo of 120bpm or 112bpm. Secondly, Experiment 4 did not use key transposition between the standard and comparison melodies; thus all melodies used in Experiment 4 were in the key of C major. Thirdly, Experiment 4 did not use any stimuli with alterations to melodic contour. Finally, all stimuli in Experiment 4 were presented using an acoustic piano timbre. The first and second methodological alterations (i.e., tempo transposition instead of key transposition) were deliberate experimental manipulations, whereas the third and fourth methodological alterations were deemed unnecessary for Experiment 4 and were thus changed to reduce the length of the experiment.
9.2.3 Apparatus

As in Experiment 3, the stimuli were manipulated using the software Propellerhead Reason 3.0 and were then converted to 44.1 kHz stereo WAV files. Stimuli were presented to participants through Sennheiser HD-650 headphones, using an Edirol UA-25 soundcard. The stimuli were presented to participants on an Acer Laptop, using the experimental software DMDX 3.1. Statistics were tabulated using Microsoft Excel XP, and were calculated using WinPsy2000.

9.2.4 Procedure

The procedure in Experiment 4 was largely similar to the procedure in Experiment 3; the sign-up procedure, questionnaire, information sheet, and consent forms were identical, and the instructions about the experiment were similar to those in Experiment 3, except where tempo transposition had to be explained instead of key transposition. The experimenter explained that all comparison melodies, even those that are otherwise the same, were tempo transpositions of the standard melodies, and explicitly informed participants that the experiment required them to ignore tempo and judge whether there were any other changes to the lengths of notes. Using a Roland KF-90 Digital Piano, the experimenter then gave examples of tempo transposition, and of same and different pairs of melodies using well-known nursery rhymes such as “Mary Had A Little Lamb” and “Twinkle Twinkle Little Star”. Before starting the experimental trials, participants were presented with twelve practice trials, on a melody based on a folk melody from the KernScores website database not used in the experimental trials (see Appendix D). As in Experiment 3, in the practice trials, participants were given corrective feedback. No feedback was given in the experimental trials.

The procedure within an experimental trial was identical to that in Experiment 3. Participants heard a pair of melodies, with an inter-stimulus interval (ISI) of 1 s, and
responded by pressing either a key on a keyboard marked “same” or a key marked “different”.

Experiment 4 had one stimulus set; in comparison, Experiment 3 had four separate stimulus sets. Experiment 4 did not vary key, and did not vary piano timbre; thus only one stimulus set was necessary. As in Experiment 3, there were 112 experimental trials in each set, with a different randomised presentation order for each participant. Over the course of the experiment, each participant would hear each melody, or a variation upon that melody, 28 times. Unlike Experiment 3, there were not equal proportions of same trials and different trials in Experiment 4; there were 64 different trials and 48 same trials. Metre alterations (MA) and pulse alterations (PA) could occur in either the standard melody – the first melody in a pair – or the comparison melody – the second melody in a pair. For each of the eight melodies used in the experiment, participants heard two ND-ND pairs, two MA-MA pairs, two PA-PA pairs, two ND-MA pairs, two ND-PA pairs, two MA-ND pairs, and two PA-ND pairs. For each type of pair (e.g., a MA-ND pair), each participant heard one pair with a 130bpm comparison melody (e.g., fast) and one pair with a 112bpm comparison melody (e.g., slow). The experiment took 50 minutes to complete.

Figure 9.2. The top of the figure shows the length of different phases of the experiment, whereas the bottom of the figure shows the structure of a typical experimental trial, where a
standard melody is followed by a comparison melody in a different tempo, and where there may be temporal alterations in either the standard or the comparison melody.

**9.3 Results**

As with previous experiments detailed in this thesis, results in Experiment 4 were analysed using planned hypothesis testing in WinPsy2000. A 2-way Analysis of Variance was performed on the results, with the kind of melody pairs used, and the length of melodies as the two independent variables. An alpha level of .05 was used for all statistical tests.

The first hypothesis in this experiment, that Hit Rate to both metre and pulse alterations when in the comparison melody in a pair of short melodies would be greater than the False Alarm Rate, was supported. The mean Hit Rate from participants discriminating metre alterations in the comparison melody \((M = 0.74, SD = 0.23)\) was significantly greater than the False Alarm Rate \((M = 0.08, SD = 0.09)\), \(F(1,19) = 134.74, p < .05, d = 3.30\). Similarly, the mean Hit Rate from participants discriminating pulse alterations in the comparison melody \((M = 0.58, SD = 0.26)\) was significantly greater than the mean False Alarm Rate \((M = 0.08, SD = 0.09)\), \(F(1,19) = 54.194, p < .05, d = 2.48\).

The second hypothesis in this experiment was that Hit Rate to both metre and pulse alterations when in the standard melody in a pair of short melodies would be greater than the False Alarm rate. The mean Hit Rate from participants discriminating metre alterations in the standard melody \((M = 0.30, SD = 0.21)\) was not significantly greater than the mean False Alarm Rate \((M = 0.25, SD = 0.23)\), \(F(1,19) = 0.517, p = n.s.\). However, the mean Hit Rate from participants discriminating pulse alterations in the standard melody \((M = 0.35, SD = 0.22)\) was significantly greater than the mean False Alarm Rate \((M = 0.21, SD = 0.14)\), \(F(1,19) = 5.694, p < .05, d = 0.649\). Thus the hypothesis was supported for pulse alterations but not for metre alterations.
Figure 9.3. Hit Rate minus False Alarm Rate to long and short melodies, with error bars indicating standard error of the mean. ND-MA indicates a metre alteration in the comparison melody; ND-PA indicates a pulse alteration in the comparison melody; MA-ND indicates a metre alteration in the standard melody; and PA-ND indicates a pulse alteration in the comparison melody.

The third hypothesis in this experiment, that HR-FA rates to both metre and pulse alterations in short melodies will be greater when the alteration is in the comparison melody than in the standard melody, was supported. In short melodies, HR-FA rates to metre alterations were greater in the comparison melody ($M = 0.65, SD = 0.26$) than in the standard melody ($M = 0.03, SD = 0.34$), $F(1,20) = 39.97, p < .05, d = 2.28$. Similarly, in short melodies, HR-FA rates to pulse alterations were greater in the comparison melody ($M = 0.48, SD = 0.30$) than in the standard melody ($M = 0.11, SD = 0.24$), $F(1,20) = 19.28, p < .05, d = 1.34$. In long melodies, HR-FA rates to metre alterations were greater in the comparison melody ($M = 0.37, SD = 0.29$) than in the standard melody ($M = -0.20, SD = 0.26$), $F(1,20) = 42.54, p < .05, d = 0.91$. Finally, in long melodies, HR-FA rates to pulse alterations were more salient in the comparison melody ($M = 0.36, SD = 0.27$) than in the standard melody ($M = -0.09, SD = 0.20$), $F(1,20) = 35.51, p < .05, d = 1.68$. Thus, the hypothesis was supported for both metre and pulse alterations in both short and long melodies.
The fourth hypothesis was that HR-FA rate to both metre and pulse alterations in the comparison melody would be greater when the alteration occurs in a short melody than when the alteration occurs in a long melody. HR-FA rates to metre alterations in the comparison melody were significantly greater in short melodies ($M = 0.65, SD = 0.26$) than in long melodies ($M = 0.37, SD = 0.29$), $F(1,19) = 22.97, p < .05, d = 1.04$. However, HR-FA rates to pulse alterations in the comparison melody were not significantly different in long melodies ($M = 0.36, SD = 0.27$) compared to short melodies ($M = 0.48, SD = 0.30$), $F(1,20) = 3.147, p = n.s.$, though this approached significance. Thus the hypothesis was supported for metre alterations and weakly supported for pulse alterations.

The fifth hypothesis was that there would be no difference between HR-FA rate to pulse alterations and metre alterations, when those alterations were in the comparison melody of short melody pairs. However, the reverse result was found; in HR-FA rates to the comparison melody of short melody pairs, metre alterations ($M = 0.65, SD = 0.26$) were significantly greater than pulse alterations ($M = 0.48, SD = 0.30$), $F(1,35) = 22.71, p < .05, d = -0.64$. Thus, the fifth hypothesis was not supported; instead, short melodies with a metre alteration to the comparison melody were more salient than short melodies with a pulse alteration to the comparison melody.

The sixth hypothesis was that, HR-FA rate to pulse alterations would be greater than their HR-FA rate to metre alterations when those alterations were in the comparison melody of long melody pairs. Measured using HR-FA, pulse alterations to the comparison melody ($M = 0.36, SD = 0.27$) were not significantly more salient than metre alterations to the comparison melody ($M = 0.37, SD = 0.29$) in long melodies, $F(1,20) = 0.02, p = n.s.$ Instead, the null hypothesis, that there was no difference between HR-FA rates to metre and pulse alterations in the comparison melody in long melodies, failed to be rejected.

*Table 9.2. Hypotheses in Experiment 4 and whether they were supported.*

<table>
<thead>
<tr>
<th>#</th>
<th>Hypothesis</th>
<th>Supported?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hit Rates in response to both metre and pulse alterations when in</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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the comparison melody in a pair of short melodies will be greater than False Alarm Rates to short melodies

II Hit Rates in response to both metre and pulse alterations when in the standard melody in a pair of short melodies will be greater than False Alarm Rates to short melodies

III HR-FA Rates in response to both metre and pulse alterations in short melodies will be greater when the alteration is in the comparison melody than when the alteration is in the standard melody.

IV HR-FA Rates in response to both metre and pulse alterations in short melodies will be greater when the alteration is in short melodies than when the alteration is in long melodies.

V HR-FA Rates in response to alterations in the comparison melody of short melodies will not differ based on whether those alterations are to pulse or are to metre.

VI HR-FA Rates in response to alterations in the comparison melody of long melodies will be greater when those alterations are to metre than when they are to pulse

9.4 Discussion

Overall, the results of Experiment 4 underscore the results of Experiment 3, suggesting that participants in both experiments were encoding melodies in a similar way, despite the different forms of transposition used in the two experiments. In Experiments 3 and 4, both pulse and metre alterations were discriminated in short comparison melodies, and pulse alterations were discriminated in both experiments when present in short standard melodies. In both experiments, pulse and metre alterations were more likely to be discriminated when they occurred in the comparison melody than in the standard melody, in both short and long melodies. In both experiments, metre alterations were more likely to be discriminated when they occurred in short melodies than long melodies, and the difference between participants’ ability to discriminate pulse alterations in short melodies compared to
long melodies approached significance. Thus, the results suggest that, in both experiments, participants are using short term or perceptual processes to encode the melodies and complete the task. That the results of Experiments 3 and 4 are largely similar even though only Experiment 4 forced participants to encode temporal information relationally suggests that participants in Experiment 3 were also encoding temporal information in a relational form.

There were some differences between Experiments 3 and 4 to do with the relative accuracy of participants’ discriminations of metre alterations compared to that of pulse alterations. In the comparison melody in long melody pairs in Experiment 3, metre alterations were significantly more salient than pulse alterations, but there was no difference in short melody pairs. In Experiment 4, in the comparison melody in short melody pairs, metre alterations were significantly more salient than pulse alterations, but there was no significant difference in long melody pairs. One interpretation of the difference between these results is that the lack of an advantage of metre over pulse alterations in short melodies in Experiment 3 reflects the presence of absolute temporal processing: when participants could process temporal information in an absolute form, there may be an increase in the salience of pulse alterations compared to metre alteration stemming from temporal perception processes (Bharucha & Pryor, 1986; Povel, 1981, 1984). In contrast, in Experiment 4, where participants were not able to process temporal information in an absolute form, the effect of absolute encoding that advantaged pulse alterations disappeared, thus leading to an increased accuracy in response to metre alterations.

The results of Experiment 4 are problematic for the assumption that memory for temporal information in melodies is reliant on general time perception processes. In neither experiment were pulse alterations significantly more likely to be discriminated than metre alterations when presented in short comparison melodies. This runs contrary to predictions made on the basis of the results of Bharucha and Pryor (1986), from which Experiments 3 and 4 were adapted. Instead, it appears that the length of notes was more influential than the extent to which those notes deviated from the temporal grid. Thus it appears likely that the processes underlying the processing of temporal information in monophonic unfamiliar tonal melodies may well be different from other forms of temporal information processing. This may be due to the
demands of melody processing in general or may be due to the demands of the specific task. However, the differences are consistent with the assumption that temporal information in Experiment 4 was being processed by a relational coding mechanism that is separate from general time perception processes (e.g., Povel, 1984).

That Experiment 4 found that temporal length seemed to be more salient to participants than deviation from the temporal grid suggests that the results of Experiments 3 and 4 can be explained using the dynamic pattern structure hypothesis of M. R. Jones and colleagues (e.g., M. R. Jones, 1993). This hypothesis posited that the perception of accents, both in time and in pitch and especially in both time and pitch, underpins the perception of music. Adding an increased focus on relational coding to the dynamic pattern structure hypothesis is the basis of the relational coding mechanism component of the model discussed in Chapter 5. For Jones and colleagues, temporally accented notes were notes that were longer than the average note; Jones and colleagues argue that these notes are remembered better than notes without temporal accents. Adding either 7/12s of a beat or a full beat to a note, as was the case in the pulse and metre alteration stimuli, respectively, in Experiment 4, therefore made that note much more likely to be temporal accented, as it made it longer than the average note. Thus, the general lack of significant differences between the discrimination pulse and metre alterations in short melodies may be because both pulse and metre alterations are simply temporally accented. Thus Experiments 3 and 4 corroborate the relational coding mechanism (see Chapter 5) and the dynamic pattern structure hypothesis, and corroborate, in a general sense, the findings of experiments such as those of M. R. Jones et al. (1982) and Monahan et al. (1987), wherein temporally accented notes (e.g., lengthened notes) were salient to participants in melody discrimination tasks and similarity judgements. As elaborated in Section 3.2.4., the dynamic pattern structure hypothesis argues that temporal and pitch information interact in memory for melodies. The relational coding mechanism also posits such an interaction. Thus, to further investigate the assumption that the dynamic pattern structure hypothesis can generally explain the results of Experiment 4, further research (e.g., Experiments 5a and 5b, in Chapter 10) will investigate the interaction between temporal information and pitch information under conditions of transposition in either key or tempo.
As Experiment 4 was largely similar to Experiment 3 in its method, except with transposition in tempo rather than transposition in key, Experiment 4 shares some methodological limitations with Experiment 3. Similar to Experiment 3, Experiment 4 used a small number of melodies, and each participant heard each melody used in the experiment, or a variation on it, 28 times. Especially considering the floor effect found in Experiment 2, where the disruption of veridical expectancies confused participants, it is likely that the results in Experiment 4 have been influenced by the presence of veridical expectancies, with previously unfamiliar melodies becoming familiar over the course of the experiment. As with Experiment 3, the randomisation of trials in Experiment 4, wherein each participant received a different random order of trials, makes it unlikely that this disruptive effect had differential effects on one condition compared to another. As with Experiment 3, the use of repetition of melodies was useful for controlling for the possible effects of particular melodies, and the way they may interact with different rhythmic alterations, and made Experiment 4 comparable to earlier experiments reported in this thesis.

In summary, Experiment 4 replicates the majority of the findings of Experiment 3, finding that metre and pulse alterations were salient, and finding that the salience of these musical features appeared to be because of their encoding by a short term or perceptual process. That the findings were still present when participants were forced to encode the melodies relationally, under conditions of transposition in tempo, suggests that the encoding of temporal information is usually in a relational form. These findings appear to cause problems for theories that assume that a temporal grid is used by memory for melodies to process temporal information, but are consistent with the idea of the salience of temporal information in memory for melodies being due to a dynamic pattern structure (e.g., M. R. Jones, 1993), such as that proposed in Chapter 5. Chapter 10 will investigate the dynamic pattern structure hypothesis further.
CHAPTER 10

Experiments 5a and 5b: Investigating the Interaction of Pitch and Time Using Garner Interference in a Melody Discrimination Task
10.1 Introduction

Chapter 10 details the final experiments in this thesis, Experiments 5a and 5b. Experiments 5a and 5b were designed to specifically test the postulate in the model in Chapter 5 that there must be some shared processing of pitch and temporal information, as melodies in memory are a coherent whole. Thus, Experiments 5a and 5b employed a Garner interference task, and used similar variables and conditions to earlier experiments in this thesis (e.g., use of transposition and use of short and long melodies). Garner interference occurs when irrelevant information from one aspect of a stimulus interferes with the processing of information from a second aspect of a stimulus; the presence of Garner interference between two aspects of a stimulus implies that those two aspects are processed by similar cognitive structures. Experiment 5a examined the effect of irrelevant temporal alterations on the discrimination of pitch alterations, while Experiment 5b examined the effect of irrelevant pitch alterations on the discrimination of temporal alterations. Experiment 5b found a significant Garner interference effect; pitch alterations interfered with the discrimination of temporal alterations. The results of Experiment 5a suggest that temporal alterations also interfered with the discrimination of pitch alterations, but the effect was smaller than that in Experiment 5b. These results suggest that there is shared processing of relative pitch and relative temporal information.

10.1.1 General Objectives of Experiments 5a and 5b

The purpose of Experiments 5a and 5b was to investigate whether there is shared processing of pitch and temporal information in memory for melodies. Such shared processing is suggested by the relational coding mechanism (RCM) in the model detailed in Chapter 5. Previous experiments in this thesis show that shared processing is plausible, given that both pitch information and temporal information appear to be encoded relationally in melody discrimination tasks such as those in Experiments 1-4. Additionally, previous research (e.g., M. R. Jones et al., 1982; Peretz & Kolinsky,
1993) suggests shared processing is likely. However, previous research did not require participants to encode material relationally and was not designed to differentiate between LTM and STM information. It is necessary to empirically address these limitations in order to study the possibility that the shared processing of pitch and time information occurs as part of the RCM.

Experiments 5a and 5b will investigate the interaction of pitch information and time information using melody discrimination tasks adapted so as to incorporate a Garner interference task (e.g., Garner, 1988; Garner & Felfoldy, 1970). Section 10.1.1 describes Garner interference tasks, Section 10.1.2 discusses research involving Garner interference tasks and memory for melodies, and Section 10.1.3 provides the experimental rationale for Experiments 5a and 5b.

10.1.2 Garner Interference Tasks

Adapting a melody for melodies task to incorporate a Garner interference task may be informative about the interaction of musical features such as pitch and time in the relational coding mechanism. Garner interference tasks resemble discrimination tasks, with the exception that two perceptual dimensions in a stimulus may be altered, but participants are instructed to pay attention to only one of them. Garner interference is thought to occur when changes to the ignored perceptual dimension of a stimulus interfere with the processing of changes to the relevant perceptual dimension. Both Hit Rates and False Alarm Rates are higher when Garner interference is present than when it is absent (e.g., Garner & Felfoldy, 1970). Garner (e.g., Garner 1988; Garner & Felfoldy, 1970) argued that the presence of Garner interference suggests that the two perceptual dimensions are integral, meaning that one cannot be processed without the other being processed. Thus, the Garner interference task can reflect the presence of shared processing in perceptual processing. If Garner interference occurs, it is likely that there is shared processing of the two perceptual dimensions; conversely, if one perceptual dimension of a stimulus does not interfere with the processing of another, then it is likely that shared processing does not occur.
If the RCM is psychologically valid, its presence should be reflected in a Garner interference task using perceptual dimensions thought to be encoded by the RCM. The RCM is informed by the dynamic pattern structure hypothesis of M. R. Jones (1993), which attempted to explain results from a variety of tasks involving memory for melodies including Garner interference tasks (e.g., M. R. Jones et al., 1982). However, the RCM differs from the dynamic pattern structure hypothesis in that the RCM emphasises the role of relational coding and emphasises the connection between the RCM and other components in the proposed model of memory for melodies; notwithstanding these differences, tasks or dimensions that are processed by the RCM should be expected to show Garner interference. The RCM encodes melodic material in a relational form, and is thought to mark, as accented, relationships between notes that denote longer notes, alterations to contour direction, and, perhaps, increases in PIM. Thus, if Experiments 5a and 5b test for Garner interference in a memory for melodies task where participants completing the task must use relational memory, in a situation that differentiates between short term and long term memory, it will be informative about the assumptions made about the relational coding mechanism.

10.1.3 Garner Interference and Memory for Melodies

Researchers have used Garner interference tasks with melodies as stimuli, and adjusted pitch and temporal information. Such research has shown that the processing of alterations to pitch information is affected by the presence of alterations to rhythm information and vice versa. In brief (see Section 3.4.2.3), research has found that the discrimination of changes to pitch information is affected by rhythmic context (M. R. Jones et al., 1982; Monahan et al., 1987; Stevens & Latimer, 1997). If a change to pitch information occurs where there is a rhythmic accent (e.g., a long note, or a note followed by a pause), the change is more salient to participants than when there is no change to rhythm, even though participants are instructed to ignore rhythmic context. As part of a neuropsychological case study, Peretz and Kolinsky (1993) included a control condition with a non-clinical sample and tested whether the presence of alterations to PIM or melodic contour caused Garner interference on a judgement about temporal information. The melodies in their experiment, which were 6 to 11
notes long, temporally consisted of an isochronous series of crotchets, with the
exception of two quavers occurring somewhere in the series of notes. Participants in
the experiment had to identify changes in the melody based on the serial position of
these quavers. There were also additional changes to either PIM or melodic contour,
which participants were instructed to ignore. Peretz and Kolinsky (1993) found that,
in this control condition, participants were distracted by the presence of pitch
alterations when there was no temporal alteration, and were aided by the presence of
pitch alterations when there was a temporal alteration. In summary, previous research
suggests that pitch information and rhythm information interact in both directions –
alterations to pitch affect the discrimination of rhythm, and alterations to rhythm
affect the discrimination of pitch.

However, because previous available research neither used transposition nor
differentiated between short and long melodies, it has not been informative about the
influence of relational memory for melodies on the interaction of pitch and temporal
information. As yet, no easily available research that has involved implicit memory
tasks in music has required participants to use relational encoding to complete the
task. Previous research (M. R. Jones et al., 1982; Monahan et al., 1987; Peretz &
Kolinsky, 1993) did not transpose melodies in key or tempo in the tasks used in their
experiments; it is therefore difficult to interpret the role of relational memory for
melodies in the results. Additionally, none of this research has used conditions that
differentiate between effects of STM and effects of LTM; again, it is therefore
difficult to interpret these experiments in terms of the role of relational memory for
melodies, as results could be caused by LTM influences rather than relational memory
for melodies. Furthermore, Peretz and Kolinsky (1993), although including alterations
to either PIM or melodic contour, did not differentiate between alterations to PIM and
alterations to melodic contour in their results. The results of Experiments 1a and 1b
reported in this thesis suggest that memory for melodic contour and memory for PIM
result partially from different cognitive processes. Thus, it is possible that the lack of
differentiation between PIM and melodic contour by Peretz and Kolinsky (1993) has
obscured different effects of Garner interference on relational memory for melodies.

In conclusion, it is clear that previous research that has analysed the interaction
between pitch and temporal information in memory for melodies is insufficient to test
the hypothesis of the relational coding mechanism. Thus, a Garner Interference Task, using transposition of melodies in key or tempo within pairs, and using a differentiation between STM and LTM information, is necessary to further test the psychological reality of the RCM.

10.1.4 Experimental Rationale

Experiments 5a and 5b were designed to investigate the presence of shared processing between pitch information and temporal information in relational memory for melodies. The methodology used by similar experiments using Garner interference tasks (e.g., M. R. Jones et al., 1982; Peretz & Kolinsky, 1993) was adapted for Experiments 5a and 5b in a way designed specifically to reflect relational memory for melodies. Thus, Experiments 5a and 5b transposed melodies in tempo and key, differentiated between long and short melodies, and differentiated between melodies with alterations to PIM and melodies with alterations to melodic contour.

Experiment 5a used identical stimuli and procedures to Experiment 5b, with one exception; in Experiment 5a participants were instructed to focus on pitch information and ignore temporal information, whereas in Experiment 5b participants were instructed to focus on temporal information and ignore pitch information. Experiments 5a and 5b used identical folk melodies to those used in Experiments 3 and 4, with pulse and metre alterations in identical serial and metric positions. However, melodies also had contour alterations and increases in PIM. Participants heard combinations of alterations to pitch and time; there were melodies with simultaneous alterations to PIM and metre, PIM and pulse, contour and metre, or contour and pulse. An additional experimental manipulation was a differentiation between melody pairs where there was a key transposition and melody pairs where there was a tempo transposition.

The aim of Experiments 5a and 5b was to determine whether the discrimination of pitch and time alterations are influenced by Garner interference. If the discrimination of contour, metre and pulse alterations appear to be unaffected by Garner interference when participants are required to use relational coding in a short term situation, it
would be unlikely that they are both processed by a perceptual processor such as the relational coding mechanism. Conversely, if contour, metre and pulse alterations are shown to be affected by the presence of ignored information in a Garner interference task when participants are required to use relational coding in a short term situation, it would provide support for the hypothesis of the relational coding mechanism.

In Experiment 5a, it is predicted that, in a Garner interference task, participants will be influenced by temporal information when discriminating pitch information, and that the effects of temporal information on pitch information will resemble the effects found in previous experiments. More specifically, it is predicted that, in Experiment 5a, where participants discriminate contour or PIM alterations, participants will be more accurate when there are simultaneous alterations to both temporal information and pitch information than when there is only an alteration to pitch information. Correspondingly, it is predicted that the opposite will occur with same melody pairs; participants will be less accurate at discriminating melodies that have no temporal alterations when there have been pitch alterations. Considering the detrimental priming effect in Experiment 1b, it is predicted that there will be a larger facilitation effect of Garner Interference on contour alterations than on PIM alterations, in both short and long melodies. Additionally, considering that, in Experiment 3 and 4, there was a larger effect of temporal length than of deviation from the temporal grid, it is predicted that metre alterations will have a larger facilitation effect on pitch discrimination (in different pairs) than pulse alterations, and a correspondingly larger interference effect on pitch discrimination in same pairs.

Additionally, and unlike previous research, Experiments 5a and 5b will compare short and long melodies, and will ensure that melodies are transposed within pairs either by key or by tempo. If Garner interference is not present when transposition has occurred it will be problematic for the RCM hypothesis. Furthermore, the presence or absence of transposition should affect the accuracy of relational memory for melodies; it should be easier to process aspects of melodies that have not been transposed (e.g., Dowling, 1978). This difference should also be reflected in the amount of interference or facilitation caused in a Garner interference task by the presence of ignored information when there is key transposition compared to tempo transposition. Thus it is anticipated that the discrimination of pitch information in Experiment 5a will be
more influenced by temporal alterations when melodies are transposed in tempo
within pairs compared to when they are transposed in key within pairs. Conversely, it
is anticipated that the discrimination of temporal information in Experiment 5b will be
influenced more by pitch alterations when melodies are transposed in key within pairs
compared to when they are transposed in tempo within pairs.

Additionally, it is predicted that, in Experiment 5b, where participants discriminate
metre or pulse alterations, participants will be significantly more accurate when there
are simultaneous alterations to both temporal information and pitch information than
when there is an alteration only to temporal information. Again, correspondingly, it is
predicted that the opposite will occur with same melody pairs; participants will be
significantly less accurate at discriminating melodies as being ‘same’ when there have
been irrelevant pitch alterations. Considering that, in Experiments 3 and 4, there was a
larger effect of temporal length than of deviation from the temporal grid, it is
predicted that pitch alterations will have a larger facilitation effect on metre
alterations than on pulse alterations, and a correspondingly larger interference effect
on temporal discrimination in same pairs. Additionally, because Experiments 1a and
1b appear to show that the processing of contour is the result of STM or perceptual
processing, and PIM is the result of LTM processes, it is predicted that irrelevant
contour alterations will lead to a larger Garner interference effect than irrelevant PIM
alterations, on the discrimination of temporal alterations in both short and long
melodies.

Finally, it is predicted that, in Experiment 5a, where pitch information is being
discriminated, similar effects to those found in Experiment 1a will be found; that is, it
is predicted that alterations to melodic contour will be more accurately discriminated
in short melodies than in long melodies, but that there will be no difference between
the rate at which increases in PIM are discriminated in short melodies compared to
long melodies. Similarly, it is predicted, in Experiment 5b, where temporal
information is being discriminated, similar effects to those found in Experiments 3
and 4 will be found; that is, it is predicted that both metre and pulse alterations will be
more accurately discriminated in short melodies than in long melodies, and predicted
that, in short melodies, there will be no difference between accuracy in discriminating
metre and pulse alterations.
10.2 Experiment 5a: Memory for Pitch Information in Melodies in a Garner Interference Task

10.2.1 Design

In a 2 x 2 x 10 repeated measures design, the within-groups independent variables were the length of melodies (short or long), the type of transposition (key or tempo) and the kind of melody alteration pair (no pitch alteration/no tempo alteration, PIM alteration/no tempo alteration, contour alteration/no tempo alteration, no pitch alteration/pulse alteration, no pitch alteration/metre alteration, contour alteration/pulse alteration, contour alteration/metre alteration, PIM alteration/pulse alteration, PIM alteration/metre alteration).

The dependent variable was accuracy. Because Experiment 5a is a Garner interference task rather than a more straightforward melody discrimination task, the metric of Hit Rate Minus False Alarm used in earlier experiments reported in this thesis is not as appropriate a metric to use for this task because in this experiment it is not salience of change that is of interest so much as levels of facilitation and interference. Thus the accuracy in correctly recognising different pairs will be calculated from Hit Rate, whereas the accuracy rate for correctly recognising same pairs will be calculated from the Correct Rejection Rate.

10.2.2 Hypotheses

In Experiment 5a, it was predicted that:

(i) Hit Rate is higher in response to discrimination of contour alterations in short melodies than in long melodies.
(ii) There is no difference between Hit Rates in response to melodies with PIM alterations in short melodies and long melodies.

(iii) Hit Rates in response to melodies with a contour alteration will be higher if there is also an alteration to the temporal information of the melody.

(iv) Hit Rates in response to melodies with a PIM alteration will be higher if there is also an alteration to the temporal information of the melody.

(v) Correct Rejection Rates in response to melodies with no pitch alterations will be higher when there are no temporal alterations than when there are temporal alterations.

(vi) Hit Rates in response to short melodies will be higher in melodies with a tempo transposition than melodies with a key transposition.

(vii) Hit Rates in response to melodies when there is an irrelevant metre alteration will be higher compared to when there is an irrelevant pulse alteration.

10.2.3 Method

10.2.3.1 Participants

Participants were either undergraduate psychology students studying at the University of Western Sydney, or graduate students studying at MARCS Auditory Laboratories at the University of Western Sydney, who reported less than two years of musical training, no hearing difficulties, no absolute pitch ability, and no speaking of a tonal language. Participants had not participated in any other experiment reported in this thesis. The 19 participants (14 females and 5 males) in this experiment had a mean age of 23.33 years (SD = 7.24) and reported an average of 1.16 years of musical training (SD = 2.57). Undergraduate psychology students received course credit for participation.

10.2.3.2 Materials
As with all other experiments in this thesis, the stimulus materials were 44.1 kHz 1411 kbps stereo WAV files that were converted from monophonic, unaccompanied MIDI files of eight melodies, that had been derived from four German folk melodies and four Irish folk melodies from the KernScores database (http://kern.ccarh.org/, 2001). The melodies used in Experiment 5a were identical to those used in Experiments 3 and 4; melodies were non-isochronous, tonal, expectable, and were created by taking the final 8 or 16 notes of a melody from the KernScores database.

As with Experiments 3 and 4, melodies were either short (8 notes long) or long (16 notes long), and all standard melodies were presented in the key of C, at a tempo of 120 beats per minute (bpm) in the time signature 4/4. As with Experiments 3 and 4, notes were accented relative to each other in intensity in order to simplify the task of determining the rhythm (see Section 8.3.2 for further details). Comparison melodies were either in the key of E, or were presented at the tempo 130bpm. All melodies were presented using a piano timbre.

As in Experiments 3 and 4, there were three types of variations to the temporal information in the melodies: a) no difference (ND) melodies; b) metre alteration (MA) melodies, where a note was lengthened for one metric beat, with further notes in the melodies moved back a beat; and c) pulse alteration (PA) melodies, where a note was lengthened for 7/12ths of one metric beat. These temporal alterations were in the same serial positions and metric positions in the melodies as those in Experiments 3 and 4.

There were additionally three types of variations to the pitch information in the melodies: a) no difference (ND) melodies; b) contour change (CC) melodies, where one note in the melody was changed so that the direction of the pitch interval between that note and both the note before and the note after it was altered from up to down, or vice versa; and c) step-to-leap (SL) melodies, where one note in the melody was changed so that a pitch interval of one or two semitones was changed into a pitch interval of four or more semitones, without altering the contour direction. These changes occurred in the same serial positions and metric positions as the temporal alterations described in the previous paragraph (see Appendix E for notated examples
of melodies used in this experiment). As with the melodies used in Experiments 1a, 1b, and 2, these changes to pitch avoided altering implied harmonies where possible.

10.2.3.3 Apparatus

The stimuli were manipulated using the software Propellerhead Reason 3.0 and were then converted to 44.1 kHz 1411 kbps stereo WAV files. Stimuli were presented to participants in a quiet room through Sennheiser HD-650 headphones, using an Edirol UA-25 soundcard. The stimuli were presented to participants using an Acer laptop, using the experimental software DMDX 3.1. Statistics were tabulated using Microsoft Excel XP, and were calculated using WinPsy2000.

10.2.3.4 Procedure

The experimenter began by giving the participant an information sheet and obtaining consent, according to the requirements of the University of Western Sydney Human Research Ethics Committee (see Appendix G for the information sheet and consent form). Participants then filled in a questionnaire that had questions about their age, gender, handedness, level of musical training, experience with languages other than English, and their possession of absolute pitch (see Appendix G).

The experimenter explained that participants were to attend to changes in pitch information and ignore changes in temporal information. The experimenter then explained that all comparison melodies, even those that are otherwise the same, were either key transpositions or tempo transpositions of the standard melodies, and explained that key and tempo transpositions thus did not count as “different” in this experiment. Using a Roland KF-90 Digital Piano, the experimenter then gave examples of transposition, and of same and different pairs of melodies using well-known nursery rhymes such as “Mary Had A Little Lamb” and “Twinkle Twinkle Little Star”. Before starting the experimental trials, participants were presented with nine practice trials using melody p823, a melody based on a folk melody from the KernScores website database not used in the experimental trials (see Appendix E). In
the practice trials, participants were given corrective feedback. No feedback was given in the experimental trials.

In each experimental trial, participants heard a pair of melodies, with an inter-stimulus interval (ISI) of one second. All pitch and time alterations occurred in the comparison melody. Participants were asked to press a button on the left side of a computer keyboard marked “diff” (the left shift key), immediately after they heard a pitch difference between the pair of melodies, or to press a button on the right side computer keyboard marked “same” (the right shift key) if they heard no pitch difference. There was an inter-trial interval of 1 s.

If each participant heard a trial corresponding to every possible stimulus pair, with equivalent amounts of same and different trials, the experimental session would have been 110 minutes long. This was considered beyond the attention span of most adults, and two separate sets of stimuli were therefore created to shorten the experimental session for participants. These stimuli sets were identical except that, for a particular trial – for example, the i0527 melody, with a contour alteration and a metre alteration – participants who received the first set heard a comparison melody with a key transposition, whereas participants who received the second set heard a comparison melody with a tempo transposition. These stimuli sets were not treated as different in statistical analysis. There were 112 experimental trials in each set, with a different randomised presentation order for each participant. Over the course of the experiment, each participant heard each melody, or a variation upon that melody, 28 times. For each of the 8 melodies in the experiment, participants heard 14 pairs. There were 6 ‘same’ pairs: 6 ND-ND pairs; 2 ‘same with rhythmic alteration’ pairs: 1 ND-MA pair, and 1 ND-PA pair; 4 ‘different with rhythmic alteration’ pairs: 1 CC-MA pair, 1 CC-PA pair, 1 SL-PA pair, and 1 SL-MA pair; and 2 ‘different’ pairs: 1 CC-ND pair, and 1 SL-ND pair. The experiment took 50 minutes to complete.

10.2.4 Results

As with other experiments in this thesis, Experiment 5a was analysed using planned hypothesis testing in WinPsy2000. However, unlike other experiments in this thesis,
Experiment 5a manipulated the presence of irrelevant and relevant melody alterations, and thus was a Garner interference task rather than a discrimination task. As a result, it was not appropriate to use the Hit Rate minus False Alarm Rate as an index of accuracy, and instead Hit Rates and Correct Rejection Rates were measured where appropriate, following the statistical methodology of Peretz and Kolinsky (1993). A 2x2x3x3 Analysis of Variance was conducted on the data, with four variables: the length of melodies, the type of transposition used, the type of pitch alteration, and the type of temporal alteration. An alpha level of .05 was used for all statistical tests.

The first hypothesis of Experiment 5a was that Hit Rates would be higher in response to short melodies with contour changes than in long melodies with contour changes. However, there was no significant difference between Hit Rates to melodies with contour changes (collapsed across transpositions in key or time, and across different temporal changes) in short melodies ($M = 0.79, SD = 0.29$) compared to long melodies ($M = 0.73, SD = 0.36$) $F(1,18) = 1.10, p > .05$. Thus the null hypothesis, that there was no difference between Hit Rates to contour changes in short compared to long melodies, failed to be rejected.

The second hypothesis was that Hit Rates in response to PIM alterations would not be higher in short melodies than in long melodies. As expected, there was no significant difference between participants’ accuracy rates in their discrimination of PIM (collapsed across transpositions in key or time, and across different temporal alterations) in short melodies ($M = 0.87, SD = 0.25$) compared to long melodies ($M = 0.86, SD = 0.28$), $F(1,18) = 0.34, p > .05$. Thus this hypothesis – the null hypothesis – failed to be rejected.
Figure 10.1. Mean proportion correct in the discrimination of pitch alterations with and without irrelevant temporal alterations, with error bars representing standard error of the mean. HR CA indicates hit rate to contour alterations, HR PIMA indicates hit rate to PIM alterations, and CRR indicates correct rejection rate with same melodies.

The third hypothesis was that Hit Rates in response to melodies with a contour alteration would be higher if there was also an alteration to the temporal information of the melody. As can be seen in Figure 10.1, there was no significant difference between participants’ discrimination of contour alterations (collapsed across melody length and type of transposition) with temporal alterations ($M = 0.78$, $SD = 0.31$) compared to those without temporal alterations ($M = 0.72$, $SD = 0.35$), $F(1,18) = 1.37$, $p > .05$. Thus the null hypothesis, that there was no difference between Hit Rates to contour alterations in melodies with temporal alterations compared to melodies without temporal alterations, failed to be rejected.

The fourth hypothesis was that Hit Rates in response to melodies with a PIM alteration would be higher if there was also an alteration to the temporal information of the melody. As can be seen in Figure 10.1, there was no significant difference between participants’ discrimination of PIM alterations (collapsed across melody length and type of transposition) with temporal alterations ($M = 0.88$, $SD = 0.24$) compared to those without temporal alterations ($M = 0.82$, $SD = 0.30$), $F(1,18) = 1.60$, $p > .05$. Thus the null hypothesis, that there was no difference between Hit Rates to
contour alterations in melodies with temporal alterations compared to melodies without temporal alterations, failed to be rejected.

The fifth hypothesis was that Correct Rejection rates to melodies with no pitch alterations (i.e., same melodies) would be higher when there were no temporal alterations than when there were temporal alterations. As can be seen in Figure 10.1, Correct Rejection Rates (collapsed across melody length and type of transposition) to melodies without temporal alterations ($M = 0.90$, $SD = 0.11$) were higher than those to melodies with temporal alterations ($M = 0.80$, $SD = 0.28$), $F(1,18) = 6.40$, $p < .05$, $d = 0.35$. Thus the results supported the fifth hypothesis.

The sixth hypothesis was that Hit Rates in response to short melodies would be higher when there was a tempo transposition than when there was a key transposition. There was no significant difference between short melodies (collapsed across temporal alteration type and pitch alteration type) under key transposition ($M = 0.80$, $SD = 0.29$) compared to tempo transposition ($M = 0.86$, $SD = 0.25$), $F(1,18) = 2.71$, $p > .05$. Thus the null hypothesis, that there was no difference between Hit Rates to pitch alterations in short melody pairs with key transposition compared to those with tempo transposition, failed to be rejected.

The seventh hypothesis was that Hit Rates to melodies with a metre alteration would be higher compared to melodies with a pulse alteration. However, there was no significant difference between melodies (collapsed across transposition type, pitch alteration type and length) where there was a metre alteration ($M = 0.83$, $SD = 0.27$) compared to melodies where there was a pulse alteration ($M = 0.83$, $SD = 0.29$), $F(1,18) = 0.00$, $p > .05$. Thus the null hypothesis, that there was no difference between Hit Rates to pitch alterations in melody pairs where there were pulse alterations compared to where there were metre alterations, failed to be rejected.

Table 10.1. Hypotheses in Experiment 5a, and whether they were supported.
<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Supported?</th>
</tr>
</thead>
<tbody>
<tr>
<td>I  Hit Rate will be higher in response to the discrimination of contour alterations in short melodies compared to long melodies</td>
<td>No</td>
</tr>
<tr>
<td>II There will be no difference between Hit Rates in response to melodies with PIM alterations in short melodies compared with long melodies</td>
<td>Yes (Null)</td>
</tr>
<tr>
<td>III Hit Rates in response to melodies with a contour alteration will be higher if there is also an alteration to the temporal information of the melody.</td>
<td>No</td>
</tr>
<tr>
<td>IV Hit Rates in response to melodies with a PIM alteration will be higher if there is also an alteration to the temporal information of the melody</td>
<td>No</td>
</tr>
<tr>
<td>V Correct Rejection Rates in response to melodies with no pitch alterations will be higher when there are no temporal alterations than when there are temporal alterations</td>
<td>Yes</td>
</tr>
<tr>
<td>VI Hit Rates in response to short melodies will be higher in melodies with a tempo transposition than melodies with a key transposition</td>
<td>No</td>
</tr>
<tr>
<td>VII Hit Rates in response to melodies where there is an irrelevant metre alteration will be higher compared to when there is an irrelevant pulse alteration.</td>
<td>No</td>
</tr>
</tbody>
</table>

10.2.5 Discussion

Experiment 5a, which sought to analyse the role of temporal variation on the discrimination of pitch alterations, found few of the effects that were expected. Firstly, there was no significant difference between Hit Rates to contour alterations in short compared to long melodies. Secondly, there was no significant difference between Hit Rates to melodies with irrelevant temporal alterations compared to melodies without temporal alterations. Thirdly, there was no difference between Hit Rates to melodies where there were irrelevant metre alterations compared to where there were irrelevant pulse alterations. Finally, there was no significant difference between Hit Rates to melody pairs with key transposition compared to melody pairs with tempo transposition.
Two expected effects were, however, found to be significant. Firstly, that of the fifth hypothesis; it was found that there was a significant difference between Correct Rejection Rates when there were not temporal alterations compared with when there were temporal alterations. This finding of Garner interference echoes that of M. R. Jones et al. (1982), who found that the presence of temporal alterations in same melodies in a similar task led to a significant decrease in accuracy; however, M. R. Jones et al. (1982) also found the reverse effect, that, in different melodies, the presence of temporal alterations led to a significant increase in accuracy; our experiment did not find this. Secondly, as expected, there was no difference between Hit Rates to PIM alterations in short compared to long melodies. It should be pointed out that this hypothesis is a null hypothesis, as it predicts a lack of difference; thus it is more appropriate to claim that this hypothesis failed to be rejected rather than to claim it was supported.

Why, then, were several predicted effects not significant in this experiment? Perhaps the most notable non-significant effect in Experiment 5a was the lack of a difference in the accurate discrimination of alterations to contour in short melodies compared to long melodies. This effect was found in Experiments 1a and 1b, and was found by Edworthy (1985a) in reaction time data. That this effect was not found in Experiment 5a suggests that the method of the experiment was not a sufficiently powerful test of participants’ ability to discriminate between melodies. Indeed, a mean Hit Rate of 0.73 in long melodies compared to a mean Hit Rate of 0.79 in short melodies suggests a trend in the expected direction; the 95% confidence intervals of the $d$ score in this comparison are -0.35 and 0.73, which reflects the lack of power in the experiment, as both a small-to-medium negative effect and a large positive effect are within the bounds of chance (see Appendix F for further statistical information about this experiment). There were positive trends in the data of other hypotheses where the null hypothesis was not rejected. For example, there was a mean Hit Rate of 0.86 for tempo transposed melodies compared to a mean Hit Rate of 0.80 for key transposed melodies, which, again, was in the direction predicted by the sixth hypothesis. Additionally, with hypotheses 3 and 4 – that there would be a Garner interference effect in different melodies for both PIM and contour – there was a non-significant trend in the expected direction for both contour alterations (0.78 with temporal
alterations compared to 0.72 without temporal alterations) and PIM alterations (0.88 with temporal alterations compared to 0.82 without temporal alterations). Because of the apparent lack of power in this experiment, it is difficult to determine whether these trends did not translate into significant differences because these trends were simply a result of noise in the data, or because they were a result of a signal in the data.

Thus, any effects of temporal variation on the discrimination of pitch are likely to be small effects, and this experiment was not sufficiently powerful to find these effects. Thus, it is necessary for future experiments to rework the methodology of Experiment 5a in order to more clearly distinguish the signal from noise. It would be beneficial for future studies attempting to rework this methodology to use a larger sample, as experimental power reflects both the variance of the sample and the amount sampled. Additionally, constraints on the length of the experiment, along with the large amount of manipulated variables in the experiment (e.g., transposition type, temporal alteration type, pitch alteration type, melody length) meant that the amount of trials for each condition was not as large as it was for earlier experiments in this thesis. Thus, it would be beneficial for future studies to have fewer conditions in order to increase the amount of trials in each condition.

In summary, few of the effects predicted in Experiment 5a translated into significant results, though many of the statistical comparisons revealed trends in the predicted directions. This may have been due to small effect sizes, or a lack of experimental power in Experiment 5a, due to the number of participants and smaller trials per condition than in other experiments. However, Experiment 5a did find a Garner interference effect in Correct Rejection Rates to melodies where there were no temporal alterations; these were significantly higher than Correct Rejection Rates to melodies where there were temporal alterations. That this experiment did not find the equivalent result in Hit Rates to different melodies is most likely a result of a lack of experimental power. Thus this experiment provides some support for the assumption that Garner interference can occur with the discrimination of pitch alterations when metre and pulse alterations are present, under conditions of key or tempo transposition – that is, when relational encoding is required.
### 10.3 Experiment 5b: Memory for Temporal Information in Melodies in a Garner Interference Task

#### 10.3.1 Design and Variables

In a 2 x 2 x 10 repeated measures design, the within-groups independent variables were the length of melodies (short or long), the type of transposition (key or tempo) and the kind of melody alteration pair (no pitch alteration/no tempo alteration, PIM alteration/no tempo alteration, contour alteration/no tempo alteration, no pitch alteration/pulse alteration, no pitch alteration/metre alteration, contour alteration/pulse alteration, contour alteration/metre alteration, PIM alteration/pulse alteration, PIM alteration/metre alteration).

The dependent variable was accuracy. Because Experiment 5a is a Garner interference task rather than a more straightforward melody discrimination task, the metric of Hit Rate Minus False Alarm used in earlier experiments reported in this thesis is not as appropriate a metric to use for this task; in this experiment it is not salience that is being measured but rather the levels of facilitation and interference. Thus the accuracy rate for different pairs will be calculated from the Hit Rate, whereas the accuracy rate for same pairs will be calculated from the Correct Rejection Rate.

#### 10.3.2 Hypotheses

1. Hit Rates in response to short melodies will be higher when there are metre alterations than when there are pulse alterations.
2. Hit Rates in response to temporal alterations will be higher in short melodies than in long melodies.
3. Hit Rates in response to melodies with temporal alterations will be higher if there is also a contour alteration than if there is no contour alteration.
(iv) Hit Rates in response to melodies with temporal alterations will be higher if there is also a PIM alteration than if there is no PIM alteration.

(v) Correct Rejection Rates in response to melodies with no temporal alterations will be higher when there are no irrelevant pitch alterations than when there are irrelevant pitch alterations.

(vi) Hit Rates in response to melodies with temporal alterations will be higher, in short melodies, when there is tempo transposition within pairs than when there is key transposition within pairs.

(vii) Hit Rates in response to melodies with temporal alterations will be higher when there is an irrelevant contour alteration than when there is an irrelevant PIM alteration.

10.3.3 Method

10.3.3.1 Participants

Participants in the musically untrained condition were either undergraduate psychology students studying at the University of Western Sydney, who reported less than two years of musical training, no hearing difficulties, no absolute pitch ability, and no speaking of a tonal language. Participants had not participated in any other experiment reported in this thesis, including Experiment 5a. The 19 participants (16 females and 3 males) in this condition had a mean age of 20.27 years (SD = 5.049) and reported an average of 1.62 years of musical training (SD = 3.77). Undergraduate psychology students received course credit for participation.

10.3.3.2 Materials

The materials used in Experiment 5b were identical to those in Experiment 5a.
10.3.3.3 Apparatus

The apparatus used in Experiment 5b was identical to that in Experiment 5a.

10.3.3.4 Procedure

The procedure used in Experiment 5b was identical to that in Experiment 5a, with one exception. In Experiment 5a participants were asked to attend to pitch information and ignore temporal information. In contrast, in Experiment 5b, participants were asked to attend to temporal information and ignore pitch information.

This difference in experimental instructions meant that the identity of same and different trials differed from Experiment 5a, though the content of trials (e.g., the presence of alterations to metre or contour) did not differ. For each of the 8 melodies in the experiment, participants heard 14 pairs. There were 6 ‘same’ pairs: 6 ND-ND pairs; and 2 ‘same with pitch alteration’ pairs: 1 CC-ND pair, and 1 SL-ND pair; 4 ‘different with pitch alteration’ pairs: 1 CC-MA pair, 1 CC-PA pair, 1 SL-PA pair, and 1 SL-MA pair; and 2 ‘different’ pairs: 1 ND-MA pair and 1 ND-PA pair. The experiment took 50 minutes to complete.

10.3.4 Results

Experiment 5b was, like Experiment 5a, analysed using planned hypothesis testing in WinPsy2000. Experiment 5b, like Experiment 5a, was a Garner interference task rather than a discrimination task and thus Hit Rates and Correct Rejection Rates were measured where appropriate, following the statistical methodology of Peretz and Kolinsky (1993). A 2x2x3x3 Analysis of Variance was conducted, with four variables: the length of melodies, the type of transposition used, the type of pitch alteration, and the type of temporal alteration. An alpha level of .05 was used for all statistical tests.
The first hypothesis of Experiment 5b was that participants would, in short melodies, have higher Hit Rates to metre alterations than to pulse alterations. As expected, there was a significant difference between Hit Rates to melodies (collapsed across transposition type and across pitch alteration type) with metre alterations ($M = 0.89, SD = 0.23$) compared to pulse alterations, ($M = 0.82, SD = 0.27$), $F(1,18) = 7.115, p < .05, d = 0.26$. Thus the first hypothesis was supported.

The second hypothesis was that participants would record a higher Hit Rate to temporal alterations in short melodies than with long melodies. As expected, there was a significant difference between Hit Rates to temporal alterations (collapsed across transposition type, across temporal alteration type, and across pitch alteration type) in short melodies ($M = 0.86, SD = 0.25$) compared to long melodies ($M = 0.74, SD = 0.33$), $F(1,18) = 15.38, p < .05, d = 0.39$. Thus this hypothesis was supported.

The third hypothesis was that melodies with temporal alterations would be more discriminable if there were also a contour alteration in the melody. As can be seen in Figure 10.2, there was a significant difference between the discrimination of pulse or metre alterations (collapsed across melody length and type of transposition) where there was an irrelevant contour alteration ($M = 0.86, SD = 0.24$) compared to where there were no pitch alterations ($M = 0.72, SD = 0.33$), $F(1,18) = 11.23, p < .05, d = 0.49$. Thus, the hypothesis was supported.

The fourth hypothesis was that melodies with temporal alterations would be more discriminable if there were also a PIM alteration in the melody. As can be seen in Figure 10.2, there was a significant difference between the discrimination of pulse or metre alterations (collapsed across melody length and type of transposition) where there was an irrelevant PIM alteration ($M = 0.82, SD = 0.29$) compared to where there were no pitch alterations ($M = 0.72, SD = 0.33$), $F(1,18) = 7.361, p < .05, d = 0.37$. Thus, the hypothesis was supported.
Figure 10.2. Mean Hit Rate in the discrimination of temporal alterations in short melodies where there were either irrelevant pitch alterations or no irrelevant pitch alterations. Error bars represent standard error from the mean.

The fifth hypothesis was that Correct Rejection rates would be higher when there were no irrelevant pitch alterations than when there were irrelevant temporal alterations. As can be seen in Figure 10.3, there was a significant difference between Correct Rejection Rates (collapsed across melody length and type of transposition) to melodies with pitch alterations ($M = 0.78, SD = 0.30$) compared to those without pitch alterations ($M = 0.92, SD = 0.10$), $F(1,18) = 8.39, p < .05, d = 0.47$. Thus the results supported the fifth hypothesis.

The sixth hypothesis was that participants would, when presented with short melodies, record a higher Hit Rate to melodies with a tempo transposition than with a key transposition. There was, however, no significant difference between melodies (collapsed across temporal alteration type and pitch alteration type) under key transposition ($M = 0.87, SD = 0.21$) compared to tempo transposition ($M = 0.84, SD = 0.28$), $F(1,18) = 0.68, p > .05$. Thus the null hypothesis, that there was no difference between Hit Rates to pitch alterations in melody pairs with key transposition compared to those with tempo transposition, failed to be rejected.
Figure 10.3. Mean Correct Rejection Rate in the discrimination of temporal alterations in short same melodies where there were either irrelevant pitch alterations or no pitch alterations. Error bars represent standard error of the mean.

The seventh hypothesis was that participants would record a higher Hit Rate to melodies where there was a contour alteration compared to melodies where there was a PIM alteration. However, there was no significant difference between melodies (collapsed across transposition type, temporal alteration type and length) where there was a contour alteration ($M = 0.86, SD = 0.24$) compared to melodies where there was a PIM alteration ($M = 0.82, SD = 0.29$), $F(1,18) = 0.95, p > .05$. Thus the null hypothesis, that there was no difference between Hit Rates to pitch alterations in melody pairs where there were pulse alterations compared to where there were metre alterations, failed to be rejected.

Table 10.2. Hypotheses in Experiment 5a, and whether they were supported.

<table>
<thead>
<tr>
<th>#</th>
<th>Hypothesis</th>
<th>Supported?</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Hit Rates in response to short melodies will be higher when there are metre alterations than when there are pulse alterations</td>
<td>Yes</td>
</tr>
<tr>
<td>II</td>
<td>Hit Rates in response to temporal alterations will be higher in short</td>
<td>Yes</td>
</tr>
</tbody>
</table>
melodies than in long melodies

III Hit Rates in response to melodies with temporal alterations will be higher if there is also a contour alteration than if there are no contour alterations

IV Hit Rates in response to melodies with temporal alterations will be higher if there is also a PIM alteration than if there are no PIM alterations

V Correct Rejection Rates in response to melodies with no temporal alterations will be higher when there are no irrelevant pitch alterations than when there are irrelevant pitch alterations

VI Hit Rates in response to melodies with temporal alterations will be higher, in short melodies, when there is tempo transposition within pairs than when there is key transposition within pairs

VII Hit Rates in response to melodies with temporal alterations will be higher when there is an irrelevant contour alteration than when there is an irrelevant PIM alteration.

10.3.5 Discussion

In contrast to Experiment 5a, where few of the predicted effects were found, most effects anticipated in the hypotheses in Section 10.3.2 were obtained in Experiment 5b; in summary, a Garner interference effect was found when melodies were transposed. As in Experiments 3 and 4, Hit Rates in response to metre alterations in Experiment 5b were significantly higher than those to pulse alterations. Additionally, as predicted, and as in Experiments 3 and 4, Hit Rates in response to short melodies were significantly higher than those to long melodies. Furthermore, as predicted, both Hit Rates in response to both pulse and metre alterations were significantly higher when there was either a contour alteration or a PIM alteration than when there was no pitch alteration. Similarly, as predicted, and as in Experiment 5a, Correct Rejection Rates were higher in response to melodies without irrelevant pitch alterations than melodies with irrelevant pitch alterations. However, there was no significant effect on Hit Rates of key transposition compared to time transposition in short melodies, and
no significant effect on Hit Rates of irrelevant contour alterations compared to irrelevant PIM alterations.

This experiment, therefore, provides support for the theory that a perceptual processor such as the RCM is responsible for the relational encoding of temporal information in melodies. As predicted by this theory, Hit Rate to temporal alterations is affected by ignored alterations to pitch - both metre and pulse alterations are more accurately discriminated when there are simultaneous alterations to either contour or PIM. Similarly, as predicted by this theory, Correct Rejection Rate is higher when there are no pitch alterations than when there are pitch alterations. Thus, an effect of Garner interference has been found in both same and different melodies. This provides strong support for the argument that there is shared processing of pitch alterations and temporal alterations, as temporal alterations were affected by pitch alterations, and the results reflect similar findings reported by Peretz and Kolinsky (1993) regarding their control group.

Additionally, Experiment 5b provides further support for the assumption that the RCM processes temporal information by temporal length rather than by deviation from the temporal grid; the finding in this experiment that metre was significantly more salient to participants than pulse is similar to findings in Experiments 3 and 4. This, therefore, further supports the theory that the processing of temporal information in memory for melodies – at least for unfamiliar, rhythmically complex melodies – is processing of temporal length rather than processing of the deviation from the temporal grid.

However, Experiment 5b found no significant difference between the effect to which irrelevant alterations to contour and PIM had on temporal alterations. This lack of a significant difference is surprising, as Experiments 1a and 1b strongly suggest that the salience of contour in melody discrimination tasks is more based on perceptual processing, whereas the salience of PIM in melody discrimination tasks is more based on a reintegration process using LTM information. Thus, contour alterations should presumably cause more Garner interference than PIM alterations. That there was not more Garner interference from contour alterations than from PIM alterations suggests that participants in a Garner interference task may process PIM differently to
participants in a standard melody discrimination task; it could be, as M. R. Jones (1993) suggests, that simultaneous alterations to PIM and to temporal information causes perceptual processing to mark such simultaneous strong accents. Additionally, contrary to expectations, this experiment obtained no difference between the effect of key transposition and the effect of tempo transposition. This lack of effect may reflect that temporal information is processed obligatorily as relational information.

In summary, Experiment 5b shows the typical Garner interference effect; Hit Rates to temporal alterations are significantly increased by the presence of irrelevant pitch alterations and Correct Rejection Rates are significantly decreased by the presence of irrelevant pitch alterations. That Garner interference occurs when melodies are transposed within trials strongly suggests that there is shared processing of temporal information and pitch information in relational memory for melodies, and it is most likely that a perceptual processor is the mechanism behind this effect.

10.4 General Discussion

The presence of Garner interference in both Experiment 5a and, more strongly, in Experiment 5b, suggests that there is shared processing of relational temporal information and relational pitch information. In Experiment 5a, there was a statistically significant effect of Garner interference from temporal alterations on Correct Rejection Rates in the discrimination of pitch alterations in melodies. Additionally, there was a trend towards an effect of Garner interference from temporal alterations on Hit Rates in the discrimination of pitch alterations in melodies. In Experiment 5b, Garner interference from pitch alterations caused an increase in Correct Rejection Rates and Hit Rates in the discrimination of temporal alterations in melodies.

That Garner interference was found in both Experiment 5a and Experiment 5b strongly suggests that there is shared processing of pitch information and temporal information. Furthermore, that Garner interference was found in an experiment that used and varied the kind of transposition used (e.g., in tempo or in key) suggests that the shared processing is fundamentally relational in nature. The effect of short
melodies being better discriminated than long melodies in Experiment 5b similarly suggests that the effects found in Experiment 5a are not due to the workings of LTM. Thus, Experiments 5a and 5b, in general, support the assumption of the relational coding mechanism in the model detailed in Chapter 5. Again, as with Experiments 3 and 4, the finding that temporal length was a better clue to discrimination than deviation from the temporal grid indicates that the relational processing of temporal information is based on the length of notes rather than their deviation from the temporal grid.

Although it is difficult to draw firm conclusions about the results of Experiment 5a compared to the results of Experiment 5b, if the results are not due to methodological considerations, they indicate that the effect of Garner interference from temporal information on pitch information is weaker than the effect of Garner interference from pitch information on temporal information. Both experiments shared stimuli, apparatus and procedures, and had similar numbers of participants, and the experiments differed only with the exception of the instructions given to participants. Yet Experiment 5a found few of the effects predicted by the model, whereas Experiment 5b found most of the effects predicted by the model. Because of the similarity in the experiments, it is unlikely that this difference between experiments is because of a lack of experimental power in one experiment compared to the other. The most obvious explanation for the difference between experimental results is that the effect of Garner interference from temporal alterations on pitch alterations in melodies is simply weaker than the effect of Garner interference from pitch alterations on temporal alterations. This lack of a symmetrical effect may have occurred because the processing of temporal information in melodies is strongly affected by the obligatory processing of pitch information, whereas the processing of pitch information is less affected by the obligatory processing of temporal information. This could indicate that the processing of temporal information in melodies is dependent on the processing of pitch, but that the processing of pitch information in melodies is less dependent on the processing of temporal information.

However, there are some alternative explanations for the results in this experiment, to do with the methods used in this experiment. Firstly, it is possible that the composition of the stimuli had some effect on the results; Experiments 5a and 5b used
the same melodies as Experiments 3 and 4, with temporal alterations in the same
temporal locations. In contrast to the temporal alterations, the pitch alterations in
Experiment 5a and 5b were added on later, and it is possible that the placement of the
alterations within the melodies was beneficial to the discrimination of temporal
alterations but somehow detrimental to the discrimination of pitch alterations.

One other possible reason for the difference in results between Experiments 5a and 5b
is that the difference has to do with the temporal location of the irrelevant stimuli.
Notes that had pitch alterations were the same notes that may have had pitch or metre
alterations. Because pulse and metre alterations involved lengthening a note, where
pitch alterations involved changing a note, a pitch alteration always occurred before a
pulse or metre alteration, as it is unlikely that participants could have been cued about
the existence of a pulse or metre alteration until it was clear that the note was longer
than it should be, whereas any pitch alteration was immediately apparent. For
example, in the 16 note melody ‘i526’, where there is a contour alteration and a pulse
alteration, the contour alteration occurs 3.26 seconds into the comparison melody,
whereas the pulse alteration only becomes clear after 3.48 seconds into the
comparison melody, because the first 0.22 seconds could conceivably be part of a
note that has not been temporally altered. Thus, it is possible that more Garner
interference was found for pitch alterations than for temporal alterations because of
this difference in temporal location. To account for this experimental limitation,
future experiments could vary the location of the pitch alteration – for example, the
pitch alteration could be in the note immediately after the temporal alteration rather
than in the same note.

One possible concern for the hypothesis that the RCM is responsible for the
processing of pitch and temporal information in melodies, is that, contrary to the
findings of Experiment 1a and 1b, Experiments 5a and 5b found little difference
between the effect of contour and the effect of PIM. In Experiment 5a, there was no
difference between the discrimination of contour in short melodies compared to long
melodies, and there was no difference between the effects of Garner interference from
temporal alterations on melodies with PIM alterations compared to melodies with
contour alterations, as neither was significant. Similarly, in Experiment 5b, there was
no difference between the effect of Garner interference from contour alterations and
the effect of Garner interference from PIM alterations. These findings are problematic for the hypothesis that the RCM is responsible, because the findings of Experiment 1a and Experiment 1b suggested that PIM was not processed by the RCM. If PIM is not processed by the RCM, an effect of Garner interference from PIM alterations should not be found. It may be that PIM alterations are accentuated by the RCM only when accompanied by temporal alterations; M. R. Jones’s (1993) hypothesis about joint accent structure suggests this. Otherwise it may be that this result is due to methodological limitations with Experiments 5a and 5b – specifically in the lack of experimental power of the experiment and in possible issues with the experimental design such as the temporal location of pitch alterations compared to temporal alterations. Alternatively, it may be that there is no difference between the processing of PIM and contour, and that the results found in Experiment 1a and 1b were influenced by methodological limitations. Future research should investigate this seeming difference between the processing of PIM in Experiments 1a and 1b compared to Experiments 5a and 5b.

In summary, although there is some uncertainty in the interpretation of the difference between the results of Experiment 5a and the results of Experiments 5b – it could be the result of a weaker effect or could be the result of methodological limitations of the experiment – the results of these experiments in general provide some support for the hypothesis that there is Garner interference from pitch information on the discrimination of temporal alterations, and Garner interference from temporal alterations on the discrimination of pitch information. This effect has occurred in experiments using methodology that has required participants to encode melodies relationally. As such, Experiments 5a and 5b provide some support for the assumption that a relational coding mechanism is responsible for the processing of temporal information and pitch information in melodies.
CHAPTER 11

*General Discussion*
11.1 Introduction

Chapter 11 provides a general discussion of the experimental research conducted in this thesis. Section 11.1.1 provides a brief recapitulation of the results found in this thesis. Section 11.1.2, which discusses the extent to which the results correspond with the model detailed in Chapter 5, suggests that the model has been verified in some respects by the results, but may need to be revised to account for how pitch and temporal information interact in the RCM, and to account for the relative contribution of LTM expectancies and the RCM to memory for melodies. Section 11.1.3 details the implications of this thesis for other areas of music cognition. This section suggests that a) theories of the evolution of music must be able to explain why features of these processing mechanisms might have evolved; b) research into acquired amusia should have a greater focus on differences between perceptual, cognitive, and LTM processing; and c) research into similarities between music processing and language processing would be improved by further research using PIM as a variable. Section 11.1.4 discusses limitations in these experiments which could lead to further research; in particular, the need for further research examining the role of veridical versus schematic expectancies, the need for further research which does not use repetition of stimuli, and the need for research using different melody lengths, different melodic types, and different substantiations of the variables in order to test the strength of the results found in this thesis. Section 11.1.5 concludes by emphasising the importance and implications of relational coding and LTM expectancies in memory for melodies.

11.1.1 General Summary of the Results of the Literature Reviews and Experimental Research in this Thesis

The general aim of this thesis was to investigate memory for melodies. A review of research on memory for melodies, and the inability of current models of vSTM or memory for melodies to satisfactorily explain experimental research, led to the formulation of a model of relational memory for melodies. The experiments reported in this thesis investigated specific hypotheses deduced from that model.
Experiments 1a, 1b, and 2 investigated the processing of PIM and melodic contour in memory for melodies. Experiment 1a found that, while participants discriminated contour alterations more often in short melodies than in long melodies, there was no difference between the rates at which participants discriminated PIM alterations in short compared to long melodies. Experiment 1b found that, while participants could discriminate contour alterations, there was no significant difference between hit rates and false alarm rates in response to melodies with PIM alterations; this was considered to have occurred because the reversing of the standard and comparison melodies meant that participants’ melodic expectancies had been disrupted. Experiment 2 attempted to disrupt veridical expectancies in particular, which led to a general floor effect. As the alteration of same melodies was the only major methodological difference between Experiment 1a and Experiment 2, this suggests that disrupting veridical expectancies affects not only the processing of PIM but also the processing of melodic contour in melody discrimination tasks.

Experiments 3 and 4 investigated the processing of pulse and metre in memory for melodies. Pulse alterations deviate more from the metric grid than metre alterations, while metre alterations lengthen an event more than pulse alterations. Experiment 3, which used key transposition within-pairs, showed little influence of long term memory processes on memory for pulse and metre in melodies; participants were significantly more likely to discriminate both pulse and metre alterations in short melodies than in long melodies. Experiment 4, which used tempo transposition within-pairs, showed that metre alterations were discriminated more accurately than pulse alterations. This result suggests that the relational coding mechanism emphasises temporal length rather than deviation from the metric grid when processing temporal events.

Using a Garner interference paradigm, Experiment 5a investigated the effect of temporal information on the discrimination of pitch, while Experiment 5b investigated the effect of pitch on the discrimination of temporal information. In Experiment 5a, Garner interference was obtained from both pulse and metre alterations on the pitch discrimination of same melody pairs, but Garner facilitation was not obtained from either pulse or metre alterations on the discrimination of either PIM or contour
alterations, though there was a trend in that direction. In Experiment 5b, Garner interference was obtained from both contour and PIM alterations on temporal discriminations of same melody pairs, and Garner facilitation was obtained from both contour and PIM alterations on the discrimination of alterations to both pulse and metre. This may suggest that the effect of Garner interference from pitch information on temporal information is stronger than the effect of Garner interference from temporal information on pitch information.

Broadly, the results of experiments detailed in this thesis suggest that memory for melodic contour is heavily reliant on a relational coding mechanism and is not facilitated by schematic expectancies, though it may be affected by veridical expectancies. The results also suggest that a relational coding mechanism is largely responsible for memory for pulse and metre in melodies. In contrast, results suggest that memory for PIM in melodies is reliant on a redintegrative process using long term memory musical expectancies. The results may also suggest that there is more Garner interference from pitch alterations on the discrimination of temporal alterations than Garner interference from temporal alterations on the discrimination of pitch.

This chapter will now investigate the capacity of the model of relational memory of melodies, and other models of music processing and/or vSTM, to explain these results, and will suggest ways in which the approach taken in this thesis might influence the interpretation of results from previous experiments. The chapter will then suggest implications of the results for the understanding of the relationship between memory for melodies and vSTM, the extent of modularity in music processing, and, more generally, the evolutionary emergence of music in humans.

11.2 The Ability of the Model of Relational Memory to Explain Experimental Results Detailed in this Thesis

The capacity of the model of relational memory for melodies to explain how contour, PIM, metre, and pulse are processed in memory for melodies was investigated in
Experiments 1a, 1b, 2, 3, and 4. Additionally, the capacity of the model to explain the interaction between pitch information and temporal information in memory for melodies was tested in Experiments 5a and 5b.

The model proposed that the discrimination of melodic contour relies on a relational coding mechanism. If this is the case, then it should be easier to discriminate alterations to melodic contour in short melodies than in long melodies, and the ability to discriminate alterations to melodic contour should be unaffected by deliberate disruptions to long term memory. Experiments 1a, 1b, and 3 each found that melodic contour was indeed more discriminable in short melodies than in long melodies; these results are similar to findings by others that melodic contour is less likely to be discriminated in tasks which rely more heavily on LTM (e.g., Dowling, 1991; Dowling & Bartlett, 1981; Dyson & Watkins, 1984; Edworthy, 1985a). Experiment 5a, however, did not find a significant difference, which suggests a ceiling effect. The disruption of expectancies in Experiment 1b did not disrupt the discrimination of contour alterations in the same manner that it disrupted the discrimination of PIM alterations. However, the disruption of veridical expectancies in Experiment 2 did disrupt the discrimination of contour alterations. The combination of these results suggests that memory for melodic contour heavily relies on a relational coding mechanism, is unaffected by schematic expectancies, but can be affected by veridical expectancies. However, it is possible that the disruption of contour evident in Experiment 2 may have been the result of a floor effect. Further research is needed to determine whether the model can account for the disruption of contour in Experiment 2 or whether the model has to be revised.

The model proposed that the ability to discriminate PIM was reliant on a redintegrative process using long term memory musical expectancies; this was supported by the results of Experiments 1a, 1b, and 2. If the discrimination of PIM was reliant on long term memory musical expectancies, then it should be expected that i) memory for melodies would not significantly differ between short and long melodies – this result was obtained in Experiment 1a; and ii), that disrupting long term memory expectancies disrupted memory for melodies – this result was obtained in Experiments 1b and 2. The combination of these results suggests that PIM is reliant on a redintegrative process using long term memory musical expectancies.
The research on PIM has two main implications for the interpretation of previous research. Firstly, it was argued in Section 3.2.2.3 that previous research, such as that of Edworthy (1985a), made changes which were interpreted as changes to tonality but which can equally be interpreted as PIM. The results of Experiment 1a confirmed that PIM is accurately discriminated, which further confirms that previous research regarding memory for tonality in melodies may have to be reinterpreted in light of research about memory for PIM in melodies. Secondly, that the discrimination of melodic contour is more accurate in short melodies than long melodies, but that the discrimination of PIM is equivalent in short melodies than long melodies, has implications for the interpretation of several experiments which have used longer melodies in melody discrimination tasks, and which have compared the discrimination of interval with the discrimination of melodic contour. For example, the experiments reported by Peretz (1990) used melodies that were between 8 and 19 notes long, and collapsed the results from all melodies in the statistical analysis; these are relatively long melodies, and it may be that Peretz’s (1990) findings would be different if shorter melodies had been used as stimuli. This therefore raises questions about Peretz’s (1990) argument for a dissociation between the processing of contour and the processing of interval. That findings can differ based on melody length, and that melody length could conceivably have affected results in past experiments points to the need for careful consideration of melody lengths used in future melody discrimination tasks.

The model proposed that the discrimination of metre and pulse was largely reliant on the relational coding mechanism. Several results obtained in Experiments 3 and 4 supported this proposition. Firstly, participants could detect changes to metre or pulse despite the presence of key transposition in Experiment 3 and tempo transposition in Experiment 4. If participants were using long auditory storage (e.g., Cowan, 1984), rather than a relational coding mechanism, the result obtained in Experiment 4 would not have been possible. Secondly, in both experiments, changes to metre and changes to pulse were both more likely to be discriminated in short melodies than in long melodies; furthermore, reversed order within-pairs did not prevent participants from discriminating melodies. Both of these sets of results suggest that the processing of pulse and metre is not heavily reliant on long term memory. Thirdly, in Experiment 4,
metre alterations were more likely to be discriminated in short melodies than pulse alterations, which confirmed the predictions of the model; in contrast, the hypothesis that general time perception processes were responsible would predict the opposite, that pulse alterations would be more likely to be discriminated (e.g., Bharucha & Pryor, 1986). Thus, the model appears to satisfactorily explain memory for pulse and metre information in memory for melodies.

The results of Experiments 3 and 4 have important implications for the interpretation of other research. Where Bharucha and Pryor (1986) found, in a task using click trains, that deviation from the temporal grid was more salient than temporal length, Experiment 4 demonstrated that temporal length was more salient than deviation from the temporal grid. The difference between the results of Bharucha and Pryor (1986) and those of Experiment 4 has important implications for much research on the perception and cognition of temporal information in music, as it shows that results from the time perception literature do not necessarily generalise to the memory for melodies literature. Thus, it may be that research which has used click-trains (e.g., M. R. Jones et al., 2002) to investigate time perception may not be representative of how time is perceived in more musical settings. This may raise questions about the capacity of theories which largely attempt to explain click-train research (e.g., Drake & Botte, 1993; Large & Jones, 1999; Povel, 1984) to explain temporal perception in more musical settings.

However, while the model has satisfactorily explained results pertaining to pitch information (i.e., PIM and melodic contour) and temporal information (i.e., metre and pulse), the results of Experiment 5a and 5b suggest that the model may have to be revised in order to account for the interaction of pitch information and temporal information. The model of relational memory for melodies divides the relational coding mechanism into three separate processes; there is relational time coding, relational pitch coding and a process which integrates pitch and time information. Such a division was proposed by Peretz and Kolinsky (1993) on the basis of their results. If, as suggested, memory for metre, pulse and melodic contour in melodies is reliant on a relational coding mechanism, then the model predicted that Garner interference and facilitation from irrelevant metre and pulse alterations should affect the discrimination of melodic contour, and that Garner interference and facilitation
from irrelevant contour alterations should affect the discrimination of metre and pulse alterations.

Experiment 5a found an effect of Garner interference on same melodies, but did not find an effect of Garner facilitation from metre and pulse alterations on the discrimination of alterations to either melodic contour or PIM. In contrast, Experiment 5b found an effect of Garner interference from irrelevant PIM and contour alterations on same melodies and an effect of Garner facilitation from irrelevant PIM and contour alterations on the discrimination of pulse and metre alterations. Neither the lack of a significant Garner interference effect in Experiment 5a, nor the effects of Garner facilitation and interference from irrelevant PIM alterations were predicted by the model. Instead, the model predicted that irrelevant PIM alterations would have little effect as PIM was thought to be largely salient because of long term memory expectancies. Similarly, the model predicted that Garner facilitation from metre and pulse alterations would be observed on the discrimination of contour, as both contour alterations and metre and pulse alterations were thought to be integrated as a melody trace by the pitch duration integration process.

Because these hypotheses were not confirmed by the results, the model may need to be revised. It appears likely, based on the present findings, that PIM is indeed processed by the relational coding mechanism; however, memory for PIM in melodies is simply less reliant on the relational coding mechanism than melodic contour. Secondly, if the effect of irrelevant pitch alterations on the discrimination of temporal alterations is larger than the effect of irrelevant temporal alterations on the discrimination of pitch alterations, the relational coding mechanism may be more focused on pitch than time, and temporal information coded by the RCM is specifically integrated into the pitch information coded by the RCM.

The results of Experiments 5a and 5b have implications for previous research. The use of transposition within-pairs meant that, while Experiment 5b replicated the finding of Garner interference from pitch information on temporal information which was reported by Peretz and Kolinsky (1993), Experiment 5a, however, did not replicate the effect of Garner interference reported by others (Jones et al., 1982; Jones &
Ralston, 1991; Stevens & Latimer, 1997). That results can, but often do not, differ when transposition is present compared to when transposition is not present suggests that memory for melodies is based on relational coding, but also that memory for melodies can use other sources of information if necessary. The broad implication here is that future research may need to control the use of relational coding to a greater extent than has been done in the majority of previous experiments.

In summary, the series of experiments reported in this thesis suggest that two aspects of the model may need to be revised: firstly, the way in which pitch and temporal information interact in the RCM; and secondly, the relative contribution of long term memory expectancies and the RCM to memory for melodic contour and memory for PIM. However, the present series of experiments also provides support for several predictions made by the model, such as the prediction that memory for PIM would be heavily reliant on LTM expectancies, and the prediction that melodic contour, metre and pulse are all heavily reliant on the relational coding mechanism.

11.2.1 Can the Results be Explained by Other Models of Short Term Memory?

No model of verbal short term memory (e.g., Baddeley, 2000) appears to be able to account for results reported here. As discussed in Section 4.4, models of verbal short term memory (e.g., Baddeley et al., 1998; Gupta & McWhinney, 1997; Nairne, 1990) are likely to have problems explaining the role of relational coding in memory for melodies. Because these models are largely focused on explaining verbal short term memory, and effects found in that literature, it is not entirely surprising that they have trouble accounting for the relational nature of memory for melodies. There do not appear to be any clear analogues of relational coding in verbal short term memory, and many models of verbal short term memory (e.g., Baddeley, 2000) provide no mechanism for temporal order, let alone relational coding. As all experiments reported in this thesis specifically used either key transposition or tempo transposition in order that participants were required to encode relationally, and as most conditions in experiments reported in this thesis found that participants were able to discriminate between melodies despite their inability to use absolute pitch information or absolute
temporal information, this series of experiments appears to confirm that most models of verbal short term memory are unable to account for the results found in this thesis, because these models ignore relational coding.

Similarly, no current model of memory for music or model of music processing appears to be able to explain the results of this series of experiments. The Garner interference and facilitation observed in Experiment 5b is problematic for the Peretz and Coltheart (2003) model, while the differential effects of LTM on different musical features is problematic for Ockelford’s (2007) model.

The Peretz and Coltheart (2003) model of music processing cannot explain several results found in the series of experiments reported here. In particular, the Peretz and Coltheart (2003) model does not appear to posit any interaction between contour analysis or interval analysis and rhythm analysis or metre analysis. Peretz and Coltheart (2003) could argue that Garner interference and facilitation from pitch information on the discrimination of temporal information, which was demonstrated in a control group in the Peretz and Kolinsky (1993) experiment, occurred while information was being processed in acoustic analysis. The effect of Garner interference and facilitation from ignored pitch information on the discrimination of temporal information found in Experiment 5b is problematic for the Peretz and Coltheart (2003) model. The use of transposition in either key or tempo within-pairs rules out the possibility that the Garner interference effect of pitch information on temporal information occurred in acoustic analysis, as the relational coding necessitated by transposition draws on what Peretz and Coltheart (2003) call the musical input modules (e.g., contour analysis). Thus, as the Peretz and Coltheart (2003) model posits no interaction between the modules which analyse pitch information and the modules which analyse temporal information, it cannot explain the findings of Experiment 5b.

Ockelford’s (2007) model of musical working memory, as discussed in Section 4.5.3, appears to have problems explaining how there is differential use of LTM in memorising different features of music. Experiments in this thesis have provided further evidence about differential use of LTM that is inconsistent with the Ockelford (2007) model. Experiment 1a demonstrated that there was no difference in the
accuracy of memory for PIM in long melodies compared to memory for PIM in short melodies, but there was a difference between memory for melodic contour in long melodies compared to memory for melodic contour in short melodies. Additionally, Experiment 1b showed that the use of reversed order within-pairs prevented the discrimination of PIM alterations, but did not prevent the discrimination of contour alterations. These findings are problematic for Ockelford’s model, and any other model of vSTM attempting to explain memory for melodies which has no obvious mechanism for explaining how LTM might be affected differentially by different musical features (e.g., Berz, 1995). Ockelford may, however, claim that such findings are limited to ‘metamusical’ tasks such as the melody discrimination tasks in this thesis, and thus do not provide strong evidence against his model; it would be fair to suggest that further research using more naturalistic stimuli is required to confirm the validity of these experiments.

The Berz (1995) model makes no predictions about the effect of LTM processes on memory for music, and thus appears to be unable to predict that PIM would be discriminated equally as well in short compared to long melodies. Additionally, because Berz did not specify the perceptual processes that feed into the model, he appears unable to explain the effect of Garner interference shown in Experiment 5b. It is thus unsurprising that the Berz (1995) model is unable to explain the results found in the present experiments.

### 11.3 Theoretical Issues

One of the aims of increasing knowledge about memory for melodies in thesis was to contribute to the debate about three issues regarding the cognition and perception of music – the extent of its modularity, the extent to which it is an evolved adaptation, and the relationship between music processing and verbal short term memory. The extent to which these issues have been illuminated by the present results is discussed in Sections 11.3.1 to 11.3.3.
11.3.1 The Relationship between vSTM and Memory for Melodies

Models of vSTM and previous models of memory for melodies do not appear to be able to explain the present results, as argued in Section 11.2.1. However, modifying the Baddeley et al. (1998) model of verbal short term memory so that perceptual processes and LTM knowledge related to language is replaced by equivalents related to music – as in the relational model of memory for melodies detailed in Chapter 5 – appears to explain many aspects of the present experimental findings. The model in Chapter 5 suggests that short term memory for melodies is equivalent to short term memory for word lists (i.e., the stimuli typically used in vSTM research). If the results of experiments such as those of Schendel and Palmer (2007), who found an effect of verbal articulatory suppression on memory for melodies and an effect of sung auditory suppression on memory for word lists, are accurate, it is likely that short term memory for melodies is similar to verbal short term memory, with the exception that the memory store interacts with different perceptual and LTM processes.

However, no experiment reported in this thesis specifically tested the hypothesis that short term memory for melodies is identical to verbal short term memory. This thesis, instead, has provided a model of memory for melodies on which to base future experiments to test this hypothesis. Additionally, this thesis has shown the importance of the use of short and long melodies, and the importance of the use of key transposition or tempo transposition within-pairs. Thus, future experiments can use these experimental techniques to isolate the cognitive mechanisms underlying memory for melodies to test its relationship with vSTM. For example, it would be informative to test whether verbal articulatory suppression affected PIM more than contour, or affected perception of longer melodies more than perception of short melodies. In summary, this thesis has posited a particular theory of the relationship between vSTM and memory for melodies – that vSTM resembles memory for melodies, except that it interacts with different perceptual processes and LTM expectancies – and this thesis has provided a model of memory for melodies that makes testable predictions which can be used to explore the relationship between vSTM and memory for melodies.
11.3.2 The Extent of Modularity in Music Processing

The arguments presented here have raised objections to the theory that general processes or linguistic processes can explain music processing (e.g., Pinker, 1997). STM models which emphasise the role of linguistic processes (e.g., Baddeley et al., 1998) do not appear to be able to explain the present results; specifically, the differential reliance on LTM musical expectancies shown in memory for PIM in melodies compared to memory for melodic contour is problematic for these theories. In contrast, modular models of memory for melodies which specifically posit perceptual processes and LTM processes – such as the model of relational memory for melodies in Chapter 5 – are able to explain these results. Thus, models which assume modularity of music processing appear to explain memory for melodies than those models which do not assume modularity.

Additionally, it has been shown that the processing of temporal information in a melody discrimination task differs from the online processing of temporal information in click-train experiments such as that of Bharucha and Pryor (1986). In the Bharucha and Pryor (1986) experiment, deviation from the temporal grid was detected more often than temporal length; by contrast, in Experiment 4, temporal length was significantly more likely to be detected than deviation from the temporal grid. Again, theories which assume that the processing of temporal information in melodies differs from the processing of temporal information in click-trains (e.g., the model of relational memory for melodies in Chapter 5) appear to be better able to explain the results of Experiment 3 and 4 than general theories of time perception (e.g., Large & Jones, 1999; Povel, 1984).

However, the review of the neuropsychological literature in Section 3.3 and the results of this thesis illustrate the need to take careful consideration of the music cognition literature in constructing a modular conception of music processing. Bergeron (2007) has argued that it is necessary to base cognitive neuropsychological research upon theories from cognitive psychology to avoid the criticism that dissociations do not reflect the existence of modules. An analysis of the literature on people with amusia, taking into consideration Dunn and Kirsner’s (1988, 2003) criticisms of much cognitive neuropsychological research, suggested that the evidence
for double dissociations between different aspects of music processing was not as strong as has been previously claimed. The results of this thesis also raise questions about previous modular conceptions of music processing (e.g., Peretz & Coltheart, 2003). The Peretz and Coltheart (2003) model does not appear to be able to explain the results of Experiment 5b, which found that an interaction of pitch and temporal information was present during relational coding. Additionally, it was argued that the distinction made between contour and interval made by Peretz (1990) was problematic, and the results of Experiments 1a and 1b appear to show that the difference between the processing of contour and interval is reliant on LTM musical expectancies; the Peretz and Coltheart model (2003) has no mechanism by which LTM musical expectancies can affect the contour analysis or interval analysis submodules. This thesis has therefore emphasised the need for neuropsychological research to be based on accurate models of music processing based on cognitive psychology research, and additionally provides a model which can be tested using cognitive neuropsychological methods with samples of people with acquired amusia.

One criticism of the model of relational memory for melodies is that it makes an assumption of modularity, and no experiment detailed in this thesis has specifically tested such an assumption. Thus, it is possible that the effects can be explained by theories which do not assume modularity. For example, if effects that mimic double dissociations can be found in damaged connectionist models (Plaut, 1995), it is possible that the effects reported here are caused not by the interaction of modules but instead by, for example, the interactions of networks of neurons that are not organised into modules. However, while effects found in testing a model with modular assumptions may well be explained by models based on other assumptions (e.g., connectionist models), at present there are no connectionist models which specifically attempt to model memory for melodies. This thesis has set out a list of results from previous research (see Chapters 3-4) and results from experiments in this thesis (see Chapters 6-10) that any model of memory for melodies, whatever its assumptions, must be able to explain.

In summary, the results of this thesis appear to be best explained by models of memory for melodies which assume modularity of music processing; in contrast, theories which assume that memory for melodies is based on linguistic processes, or
that the processing of temporal information in memory for melodies is based on
general time perception processes, have difficulty explaining the present results. It is
possible that other models with different assumptions, such as connectionism, may
also be able to explain the results of this thesis; however, at present no connectionist
models are available which do so.

11.3.3 The Evolutionary Emergence of Music Processing

It was emphasised in Chapter 2 that the study of the evolution of cognitive
mechanisms involved in music would be enhanced by further knowledge of the
cognitive mechanisms involved in memory for melodies. As argued in Chapter 2,
memory for melodies appears to be one of the cognitive mechanisms underlying
music perception and music cognition which is most likely to be an adaptation caused
by natural selection. As such, one of the aims of this thesis was to expand knowledge
about memory for melodies.

It was not an aim of the thesis to create a new theory about the evolutionary
emergence of relational memory for melodies. Rather, the thesis reports several
effects which any theory about the evolutionary emergence of relational memory for
melodies must be able to explain. Specifically, this thesis provides evidence that there
is a perceptual process which underlies memory for melodies and which appears to
code musical features like metre, pulse, and melodic contour in a relational form.
Secondly, this thesis provides evidence that memory for PIM in melodies appears to
be more reliant on LTM melodic expectancies than on the relational coding
mechanism. Thirdly, this thesis provides evidence that the processing of the musical
features of metre and pulse differs when those musical features are contained within a
melody compared to when those musical features are contained within a click-train;
these features appear to be encoded relationally by a specialised perceptual process
rather than by general time perception processes. Finally, the thesis provides evidence
that, when relational coding is necessary, there is an interaction between pitch and
temporal information which causes Garner interference; however, the Garner
interference from pitch on the discrimination of temporal information appears to be
stronger than the Garner interference from temporal information on pitch.
Theories which attempt to explain the evolution of memory for melodic contour (e.g., Cordes, 2003) must be able to explain the aforementioned results, insofar as it is plausible that the aforementioned features of memory for melodies could be present in music processing in a prehistoric evolutionary environment. Cordes (2003) argues that melodic contour is salient because it is a meaningful feature of mother-infant communication. Thus, in light of the research presented here, theories such as those of Cordes (2003) must also be able to explain why i) it might have been advantageous to code metre, pulse, and melodic contour in a relational form; ii) PIM is reliant on LTM melodic expectancies rather than on the relational coding mechanism; iii) why pulse and metre in melodies might be processed differently to those features in general time perception; and iv) why the effect of Garner interference from temporal information on pitch information found in Experiment 5a is weaker than the effect of Garner interference from pitch information on temporal information found in Experiment 5b. For example, a theory like that of Cordes (2003) might argue that i) relational coding is useful because it enables the communication of complex information in a way that absolute coding does not; ii) PIM is not as meaningful a feature of mother-infant communication as melodic contour; iii) temporal length is the most meaningful feature of temporal information in mother-infant communication; iv) alterations to pitch information carry more meaningful information in mother-infant communication than temporal information. Each of these arguments can be explored empirically.

In summary, this thesis has contributed to the issue of the evolutionary emergence of cognitive mechanisms related to music cognition and music perception by increasing knowledge about the mechanisms underlying memory for melodies. If the relational coding mechanism is an adaptation caused by natural selection, theories attempting to explain why the relational coding mechanism might have emerged in a prehistoric environment must explain results reported here and in previous research.

11.4 Limitations and Ideas for Future Research

One limitation which can be rectified with future research concerns the way that the seven experiments reported in this thesis were not able to resolve theoretical issues in
the study of relational memory for melodies. This inability to resolve major issues was because the experiments attempted to answer three separate but linked research questions (i.e., the effect of LTM on PIM and contour, the role of the relational coding mechanism in the ability to discriminate pulse and metre alterations, and the presence of Garner interference from temporal information on pitch information and vice versa) each of which was under-represented in past research, and each of which tested a different aspect of the model of relational memory for melodies. Each of these three separate research questions requires further research to clarify unresolved issues.

In the series of experiments which investigated the effect of LTM expectancies on the discrimination of alterations to PIM and contour, reported in Chapters 6 and 7, one unresolved issue was the relative contribution of schematic expectancies and veridical expectancies to memory for melodies. Experiment 1b did not distinguish between priming effects caused by veridical expectancies and priming effects caused by schematic expectancies. Experiment 2 was designed to distinguish between the effect of veridical expectancies and schematic expectancies on memory for melodies; however, the floor effect in Experiment 2 meant that the relative contributions to memory for melodies of these two kinds of expectancies could not be determined. One problem with Experiment 2 was that the melodies used in that experiment were heard several times over the course of the experiment (with small variations). Thus, while Experiment 2 was designed to prevent participants from using veridical expectancies to complete the task, it instead may have led to veridical expectancies developing that disrupted the task. Thus, where an experiment such as Experiment 2 used 16 different unfamiliar melodies over 128 trials, a new experiment could use, say, 32 or 64 different unfamiliar melodies over 128 trials, with a rolling experimental design so that, while each participant might only hear 128 different melodies in a particular experimental session, over the course of several experimental sessions, each of those 128 melodies would be heard with different alterations. Such an experiment would avoid the effects of the development of veridical expectancies, as participants will not have previously heard the melody in any other trial during the experiment. Such an experiment would also be a closer parallel to research in vSTM; there is rarely as much repetition of lists in vSTM serial recognition tasks (e.g., Nimmo &
Roodenrys, 2006) as there was repetition of melodies in the experiments reported in this thesis.

Experiments 3 and 4 share a limitation with Experiments 1a, 1b, and 2, in that participants in those experiments would hear each melody (or a variation upon that melody) 28 times. Thus, it is possible that the results of Experiments 3 and 4 are due in part to priming effects, whereby implicit learning about the melodies affects participants’ ability to discriminate between melodies. For example, implicit learning from a previous presentation of the melody may interfere with the participants’ perception of the standard melody when the participant is discriminating between the standard melody and the control melody. This possible effect of implicit learning is a problem for the interpretation of results, because it is unclear what proportion of the results is due to perceptual processes, and what proportion is due to implicit learning. As pulse alterations seemed to be more reliant on LTM processes than metre alterations, it is likely, in this experiment, that in an experiment with fewer repetitions of melodies, that pulse alterations will be less salient to participants. As detailed in Section 8.5, the repetition of melodies within the experiment was part of the experimental design because it led to greater experimental control. However, it would be beneficial for future research to avoid priming effects, and thus a follow-up experiment could avoid repetition of melodies within the experiment, with 112 different unfamiliar melodies in 112 trials (where, in Experiments 3 and 4, there were 8 different unfamiliar melodies in 112 trials).

There are limitations to Experiments 5a and 5b which can also be resolved in future experiments. As with previous experiments in this thesis, it is possible that there are priming effects as a result of the repetition of melodies in Experiments 5a and 5b; as with previous experiments in this thesis, future experiments which avoid the repetition of melodies are needed to differentiate effects caused by priming from effects caused by perceptual processes such as the relational coding mechanism. Additionally, future experiments are needed to elucidate some of the more puzzling findings from Experiments 5a and 5b. For example, in Experiment 5a, that there was no difference between the effects of Garner interference on the discrimination of temporal alterations from irrelevant contour alterations compared to the effect of Garner interference on the discrimination of temporal alterations from irrelevant PIM
alterations was not predicted by the model. It would be beneficial for future research to explore whether this effect was the result of, for example, priming effects. Additionally, Experiments 5a and 5b had many conditions (e.g., short vs long, tempo transposition vs key transposition, contour vs PIM, and metre vs pulse) and this may have limited the amount of data in each condition. Future experiments could either remove some conditions (e.g., temporal change type or transposition type) from the experimental design, or could replicate the experiment with larger samples.

Furthermore, it should be emphasised that all of the experiments detailed in this thesis were conducted with participants who completed the experiment in return for course credit in a first-year psychology class, or participants with musical training recruited from the general community. That most, if not all, of the participants are familiar, through exposure, with Western tonal music has particular implications for research on music cognition such as those detailed in this thesis. Music from the Western cultural tradition often has more complex harmonic information and less complex temporal information than music made in cultures such as the Ewe of West Ghana (Pressing, 1983). Thus, it is problematic to generalise from the results of this experiment to music cognition in general, as the cognitive mechanisms which process music in people from other cultures may differ substantially to those of people familiar with Western culture. This can especially be a problem with arguments about the evolutionary emergence of music, as the use of music in modern Western culture is likely to be substantially different from the use of music in the prehistoric environments and species in which the cognitive mechanisms underlying human memory for melodies may have evolved (Blacking, 1972; Mithen, 2005). Thus, future research should attempt to replicate the present findings using participants from cultures with substantially different musical traditions to those of Western culture.

There are limitations in the validity of these experiments to do with the particular melodies and melody lengths. As Ockelford (2007) points out, melody discrimination tasks are metamusical rather than musical because they use stimuli without the complexity and meaningfulness of ‘real’ music. While pre-existing folk melodies without changes to the original temporal information were used in this experiment because they were considered to be less metamusical than isochronous stimuli composed specifically for the experiment, it should be pointed out that it is possible
that the folk melodies used in this experiment are unrepresentative of music in general. In particular, the majority of music heard by Western listeners is polyphonic and contains more than 16 notes. The result reported by Dowling et al. (2002), that participants can accurately discriminate changes to melodic themes even when the standard melody and the comparison melody are separated by several bars of subsequent coherent musical information, is an illustration that findings from metamusical tasks may not apply to memory for music in general; this is also illustrated by the difference between the findings in Experiment 4 and the findings of Bharucha and Pryor (1986) regarding the relative salience of temporal length and deviation from the temporal grid. This empirically demonstrated difference between musical tasks and metamusical tasks implies that the assumption that the findings are valid should be tested. Future research using more musical tasks, such as a variation of the task used by Dowling et al. (2002), and less metamusical stimuli, such as polyphonic melodies which have a natural progression of musical tension and resolution in them, could be used to replicate the present experiments and results, such as the finding in Experiment 4 that temporal length is more salient than deviation from the temporal grid, and the relative contribution of LTM knowledge to memory for melodic contour and memory for PIM in melodies.

Future research that investigates the implications of these results for neuropsychological research with people with acquired amusia is necessary. If the model detailed in Chapter 5 is a better explanation of memory for melodies than the model of Peretz and Coltheart (2003), then the model detailed in Chapter 5 may also be more informative about acquired amusia. The results shown in this thesis suggest that relational coding is common to the processing of melodic contour, metre and pulse. As such, tasks used to test the presence of acquired amusia which use relational coding by transposing melodies within-pairs may be more informative about the nature of that acquired amusia; if people with acquired amusia are unable to discriminate between transposed melodies where they are able to discriminate between untransposed melodies, it would suggest that there is damage to the relational coding mechanism. Peretz (1993) reports a case of atonia where the participant is unable to discriminate melodies on the basis of tonality, but is able to discriminate melodies on the basis of contour and, to some extent, interval size. The model detailed in Chapter 5 would predict such a result if there was damage to the redintegrative
process detailed in the model, or if there was damage to stored schematic expectancies. If damage to the cognitive mechanisms posited in the model detailed in Chapter 5 have caused many cases of acquired amusia, then the application of the model to the study of acquired amusia may increase knowledge of the cognitive mechanisms that underlie particular forms of acquired amusia. This therefore may lead to more effective treatment.

Another way in which the model and the results detailed in this thesis may contribute to future research is in the study of what Sacks (2007) refers to as earworms. Earworms are excerpts from songs or melodies which get ‘stuck in the head’ regardless of any desire to listen to them. For example, many participants in experiments detailed in this thesis stated in post-experimental interviews afterwards that melodies from the experiment had already become earworms. The model in Chapter 5 is a model of memory for melodies, so the model should theoretically be able to explain the processes by which earworms occur. Such research would assess the memorability of a melody by varying the amount of repetition in the melody, and the extent to which the schematic expectancies of the melody lead to tension and release. Additionally, research could assess the correlation between the coherence of the joint accent structure of the melody (e.g., the amount of lengthened notes, and the amount of contour changes and increases in PIM) and the likelihood that the melody will be stuck in the head. Such research could benefit composers, musicians and the music industry, as there is likely to be a correlation between the likelihood of a song becoming an earworm and its commercial success; on the other hand, results in the present research could be used to develop defence mechanisms against repetitive novelty songs.

11.5 Conclusion

A broad aim of this thesis was to expand knowledge about memory for melodies in order to contribute to various debates occurring within the field of the perception and cognition of music. A literature review determined that it was necessary to draft a new
model of relational memory for melodies in order to increase knowledge about memory for melodies, and experiments were conducted investigating specific aspects of this model.

The present experimental results have emphasised the importance of relational coding in memory for melodies, and have shown the influence of LTM expectancies on memory for melodies. The model of memory for melodies detailed in Chapter 5 appears better able to explain these results than previous models of memory for melodies or models of verbal short term memory. The present results have implications for current issues in the study of music cognition and music perception. The present results have contributed to the study of the evolutionary emergence of music by expanding knowledge of memory for melodies and providing a list of effects which evolutionary theories of memory for melodies must explain. Additionally, where verbal short term memory appears to be reliant on perceptual processes and LTM knowledge related to phonology (e.g., Gupta & McWhinney, 1997), memory for melodies appears to be more reliant on a relational coding mechanism and schematic and veridical expectancies. Finally, results such as the difference between the processing of temporal information in click-trains compared to melodies provide evidence for the modularity of music processing.
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APPENDIX A. Definitions of memory for melodies and melodic contour

A.1 Defining Memory for Melodies

Memory for melodies has been explicitly characterised as a relational form of memory (J. Davies, 1979; Deutsch, 1969; Dowling, 1978). There has been extensive research on pitch memory (e.g., Deutsch, 1972, 1975; Zatorre et al., 1994), where researchers examine a person’s ability to identify pitches presented after intervening distractor tones; this research sometimes places these pitches within melodies, where other notes of the melody are the distractor tones. However, pitch memory should not be thought of as the same as memory for melodies; where pitch memory is a form of immediate perceptual memory, memory for melodies is a memory for the relationships between pitches and therefore involves either abstraction or the recognition of higher-order configurations (J. Davies, 1979). This is borne out by the observation that we are capable of recognizing a melody such as “Happy Birthday” whether it is sung in the key of F major or the key of B major, though the melody of “Happy Birthday” in F major shares no pitches with the melody of “Happy Birthday” in B major. J. Davies argues that melody is “a function of the listener’s ability to organise or chunk tones into meaningful perceptual patterns and forms” (1979, p. 205), and that melody is thus more than just a sequence of tones. As such, memory for melodies is more equivalent to memory for sentences than memory for lists of words, and involves top-down processing.

A.2 Defining Melodic Contour

Melodic contour is considered by most researchers working in the area of memory for melodies (e.g., Dowling, 1978; Edworthy, 1985a; Peretz, 1990) to be a global feature
of melody which is salient to listeners. It is defined by Dowling (1982) as the ups and downs in pitch of melody, without reference to the size of those ups and downs in terms of interval. Additionally, it should be pointed out that cognitive psychologists largely view melodic contour as a note-to-note property of a melody; cognitive psychologists have rarely attempted to manipulate the global shape of a melodic contour, or measure its salience (though see Lamont & Dibben, 2001). While this definition is largely accepted within the cognitive neuroscience of music (e.g., Peretz, Champod, & Hyde, 2003), definitions of melodic contour within other musicological disciplines such as music theory and ethnomusicology differ.

A.2.1 Ethnomusicological Research on Melodic Contour

Beyond the obvious difference in that cognitive psychologists often refer to ‘melodic contour’ when they mean ‘the cognition of melodic contour’, and ethnomusicologists refer to ‘melodic contour’ and mean ‘melodic contour’ (i.e., the property of the stimulus), it appears that ethnomusicologists (Adams, 1976; Lomax, 1968) treat melodic contour as a more global property of music than cognitive psychologists. For an ethnomusicologist, changing an up to a down in a melody in the manner characteristic of cognitive psychologists such as Edworthy (1985a) or Peretz (1990) would not necessarily change the melodic contour. Lomax’s (1968) Cantometrics project, which attempted to statistically analyse the properties of music from different cultures and relate those statistical properties of music to differences in culture, discovered differences in the types of contour found on different continents. Lomax (1968) categorised melodies as either having 1) prominent use of arched phrases, those which rise and then fall, 2) prominent use of undulating phrases, those which have a wave-like shape, 3) an overall terraced shape; these are melodies which, overall, descend, but with individual phrases which start above the pitch level of the end of the end of the last phrase, giving a terraced shape or 4) prominent use of descending phrases, those which exclusively fall. These classifications, which are explicitly global in nature, have been used by ethnomusicologists to compare musics from different cultures; for example, descending contours were unusually prominent in the sample of the indigenous musics of Africa, and terraced contours were unusually prominent in the sample of the indigenous musics of North America, and
ethnomusicologists. This should be contrasted with the view of melodic contour held by cognitive psychologists, who rarely analyse melodic contour with reference to its overall shape, but instead analyse the note-to-note pattern of ups and downs (though see Lamont & Dibben, 2001); note-to-note patterns are by definition less global than the overall shapes such as terraced shapes theorised by ethnomusicologists. It should also be noted that the magnitude of the pitch intervals in the melodies are implicitly part of the definition of melodic contour for Lomax (1968) and Adams (1976); the terraced shape specifically implies a leap at the start of the melody, as the terrace shape is characterised by large leaps either at the start of phrases, or between the end of one phrase and the start of another.

### A.2.2 Music Theory and Melodic Contour

Music theorists (e.g., Marvin, 1993; Marvin & Laprade, 1987; Morris, 1993) have attempted to broaden the conception of contour in music, suggesting that cognitive psychologists focus too much on the contours of adjacent notes, and focus too much on pitch. Morris (1993) has argued for a theory of musical contour, claimed to be based on Gestalt psychology principles. For Morris, musical contour is broader than melodic contour, and musical contours may be based on dynamics or chord density in time, for example, rather than pitches in time. Morris introduces a contour reduction algorithm, which finds a global contour by the process of examining sets of three successive pitches, finding changes in direction, and reducing the melody to those changes in direction. Notes which do not reflect a change in direction are ‘pruned’. For example, consider a sequence of pitches such as CEFEDFECFEC. A reduction according to the algorithm proposed by Morris (1993) would prune this melody to CEFEDFECFEC, where the pruned notes are indicated in grey and the retained notes are indicated in black. A second reduction would compare the maxima (e.g., the F’s) and minima (e.g., the C’s and D) separately, and would reduce the melody to CEFEDFECFEC. Marvin (1993) has put together a theory of ‘rhythmic contour’ broadly analogous to the Morris algorithm, except duration is used as input rather than pitch.
No empirical research has tested whether the contours identified by Morris’s (1993) algorithm or the rhythmic contours of Marvin (1993) correspond to the cognition of musical contour by adult humans. In contrast, theoretical models of melodic contour similarity such as that of Marvin and Laprade (1987), which develop ways of quantifying the similarity of contours, and which incorporate measures of the importance of contours based on nonadjacent notes, have been tested empirically. Quinn (1999) found that, using stimuli based on theories like that of Marvin and Laprade (1987), participants with musical training used contour relations between nonadjacent notes in judgments of contour similarity.

A.2.3 Conclusions from Musicology and Ethnomusicology about the Nature of Melodic Contour

Two themes emerge from a consideration of the ethnomusicological and music theory research on melodic contour, which have important ramifications for a discussion of the cognitive psychology and neuroscientific literature regarding melodic contour. Firstly, it may be that contour in melody is not the only form of contour which is perceptually salient; other features of music, such as dynamics or rhythm, could potentially have perceptually salient contours. This, however, is an empirical question that has not yet been answered. Secondly, considerations and measurements of melodic contour in ethnomusicology (e.g., Adams, 1976; Lomax, 1968) and music theory (e.g., Morris, 1993; Quinn, 1999) treat melodic contours at the level of their global shape (e.g., terraced contours, or the reduction of a melody to a contour). In comparison, as we shall see, cognitive psychology research has largely focused on changes to contour at a more local level. The nature of cognitive psychology experiments is to avoid ceiling or floor effects. This, then, requires a focus on the point where a change is salient, which in practice requires a focus on a more local level of melodic contour than the global shape. This may cause problems for cognitive psychologists (e.g., Peretz, 1990), who argue that changes to the melodic contour and changes to interval sizes as global and local changes, respectively. As this thesis will use the techniques of cognitive psychology, we will avoid any claim that melodic contour is global, at least in its typical use in psychological research.
APPENDIX B. Further Discussion of Evolution

B.1 Humans are evolved creatures related to the apes

A variety of evidence from comparative biology, palaeontology and DNA studies indicates that humans are evolved creatures which have been subject to natural selection (e.g., Dawkins, 1986; Pinker, 1997). *Homo sapiens* appears to be most similar physiologically to the great apes – chimpanzees, bonobos, gorillas, gibbons, and orangutans – with whom we share many physiological characteristics unusual to other mammals, such as flat fingernails and toenails, hands for gripping, opposable thumbs, and a lack of a tail (Diamond, 1991). This suggests that humans are genetically related to the apes; DNA studies have in fact shown that humans are most closely related to chimpanzees and bonobos. Measurements of the amount of mutations to DNA suggest that the human and chimpanzee species diverged about 6 or 7 million years ago, and that the chimpanzee and bonobo species diverged shortly afterwards.

Evolution works by the mechanism of natural selection. Natural selection occurs due to the incremental changes from the interaction of variation, survival and reproduction. Animals which are better able to survive to reproductive age and better able to reproduce are more likely to leave offspring. Mutations beneficial to the survival and reproduction of an animal, which get passed onto an animal’s offspring, are likely to make that offspring better able to survive and reproduce than animals that do not have these mutations, and thus these mutations are likely to become a dominant trait of a species given enough generations. The ‘modern synthesis’, popularised by the likes of Dawkins (1986) and Gould (2006), combines this Darwinian evolutionary logic with Mendelian genetic theory and knowledge about the mechanisms involved in DNA, along with modern knowledge about population genetics, the mathematical modelling of genetic variation within a population, which have added to the force of evolutionary explanations (Dawkins, 1986). There are
several processes by which genetic variation occur. Firstly, the process of meiosis; when male genetic material fertilises the female’s egg, half of the chromosomes from the male and from the female are retained, resulting in each fertilised egg having a unique recombination of DNA, as not only does the fertilised egg have half its chromosomes from each parent, but the process also includes some swapping of genes between chromosomes from different parents, so siblings are not identical (Dawkins, 1986). Secondly, there appears to be a steady rate of random mutations to the structure of DNA across a species in time, much of it in areas of ‘junk DNA’, but some of it in places which might cause either beneficial or detrimental mutations (Dawkins, 1986). Dawkins (1986) argues that the unit of natural selection – the most influential actor upon evolution - is the gene. In this sense, organisms are merely hosts for genes; this argument can explain the seeming evolutionary selflessness of worker bees, which are infertile in most bee species, and which contribute to the maintenance of a beehive. Worker bees, which largely share genes with the rest of the hive, are essentially, according to Dawkins (1986) protecting the interests of their genes, rather than themselves. Gould (2006), a palaeohistorian, while agreeing that the gene can be the unit of selection, also points out that historical forces have acted upon evolution, and that the species often appears to be the unit of selection; according to Gould (2006), the arguments of Dawkins (1986) and others often make it appear as if an evolved mechanism is the best possible mechanism for a particular environment, when that evolved mechanism is the result of a conjunction of historical forces and the limitations of the mechanisms by which genetic mutations occur. However, there is more similarity than difference between Gould’s and Dawkins’ theoretical positions; the argument is about prevalence of evolutionary mechanisms rather than the nature of evolution.

**B.2 A brief history of human evolution**

A variety of palaeontological evidence appears to show the progression between the species ancestral to both humans and chimpanzees, to present-day humans. The earliest known hominin fossil belongs to a species designated as *Ardipithecus ramidus*, found in Ethiopia and dated to 4.5 million years ago; however, there is an earlier specimen, *Sahelanthropus tchadensis*, which has been argued to be a hominin
(Brunet et al., 2002), but may be more ancestral to gorillas. *Ardipithecus ramidus* appears to be less like modern humans and more broadly similar to modern day apes – it was the size of a chimpanzee and had chimpanzee-like teeth. However, the opening to the skull through which the spinal cord passes is below the skull rather than to its rear, which indicates some uprightness of posture, and toes which appear to be adapted to bipedalism; these are the first evidence of the essential difference between the hominids and other apes (Mithen, 2005). There is a clear progression from *Ardipithecus ramidus* to *Australopithecus afarensis*, of which the most famous, and most complete, specimen is popularly known as ‘Lucy’, which dates from between 3.5 million years ago. *Australopithecus afarensis* appears to have smaller, more human-like teeth than *Ardipithecus ramidus*, and a body more suited to savannah living (Mithen, 2005).

*Homo habilis*, the oldest species which palaeontologists place in the same genus as modern humans, dates to around 2.5 to 1.8 million years ago, and is the first species which appears to use stone tools. *Homo habilis* has a larger brain than the *Australopithecines* and smaller teeth, a larger body, and appeared to have been adapted to eating meat (Mithen, 2005). By 1.8 million years ago, *Homo ergaster* had evolved. *Ergaster* (and the similar species *Homo erectus*) would have been able to walk, run and jump in much the same way modern humans do today. It had a lowered larynx as a result of its bipedalism, and had a brain size of about 80 per cent of modern humans. Additionally, *Ergaster* had advanced tool making, including cleavers and handaxes, and the first undisputed use of controlled fire appears to have been the result of *Homo Erectus* (Mithen, 2005). *Homo Neanderthalensis*, the Neanderthal Man common to Europe, appears to have developed around 230,000 years ago, and died out 30,000 years ago; Neanderthal Man does not appear to have been ancestral to modern humans (Mithen, 2005). Physiologically modern humans appear to have appeared by 250,000 years ago in Africa. Finally, Diamond (1991) and other palaeohistorians refer to the *Great Leap Forward*, which happened 60,000 to 50,000 years ago, and which involves the first evidence of art and different artistic styles, sophisticated hunting techniques, and the comparatively rapid colonisation of much of the globe.
B.3 More detail about theories of how to determine the presence of adaptations

B.3.1 The debate between Hauser, Chomsky, and Fitch and Pinker and Jackendoff.

There has been a debate between Hauser, Chomsky, & Fitch (2002; henceforth, HCF) and Pinker & Jackendoff (2005; henceforth, P&J) about the evolution of language based on differing criteria for considering a brain mechanism an adaptation. Using the example of the language faculty in the brain, Hauser et al. (2002), argued that it was useful to underline the difference between “the faculty of language in the narrow sense” (FLN) and “the faculty of language in the broad sense” (FLB). HCF define FLN as those elements of human language which are unique to humans and which are uniquely used in language. In contrast, FLB is defined as any mechanisms in the brain involved in language in some way. HCF (Hauser et al., 2002; Fitch, Hauser, & Chomsky, 2005) argue that the FLN is quite limited, and they argue that it may be specifically the use of recursion in language. Recursion is behind the ability possessed by humans to produce sentences that could theoretically be infinitely long; this ability enables us to understand sentences which are more semantically complex than “lion!” or “run away!” . For example, the sentence ‘((((the hole) in the tree) in the glade) by the stream) in the forest) by the plain) between the mountains) in the north of the island)’ (Fitch, et al., 2005) is recursive, with the recursions indicated by the brackets. One could extend this sentence to infinity, pointing out the relationship of the hole in the tree to an infinite amount of things; this ability is recursion. As a mechanism for recursion, Hauser et al. (2002) suggest the statistical language learning faculty proposed by Saffran and colleagues (e.g., McMullen & Saffran, 2004; Saffran, 2003); Saffran argues that the acquisition of language in infants is facilitated by the infants’ ability to statistically analyse the stream of speech produced by others and segment it into words and sounds. In contrast, P&J (Pinker, 1993; Jackendoff & Pinker, 2005; Pinker & Jackendoff, 2005) argue that FLN is quite complex, and that elements of speech perception and production, phonology, memory, and some concepts have been specifically evolved for language.
One reason why this debate between P&J and HCF has arisen is their different theoretical and philosophical beliefs concerning the evolution of brain mechanisms. Hauser, Chomsky, & Fitch see evolution ahistorically; they dismiss arguments about the evolutionary environment as speculation, based on scant evidence (Fitch et al., 2005). To Hauser, Chomsky, & Fitch, if a brain mechanism is vital to a particular domain (e.g., recursion in language) and unique to a particular species (e.g., *Homo sapiens*), that brain mechanism can be said to be the result of adaptation by natural selection. In contrast, Pinker (e.g., Pinker, 1993; Pinker & Jackendoff, 2005) uses the evolutionary psychology paradigm developed by Tooby & Cosmides (e.g., Barkow, Tooby, & Cosmides, 1992; Tooby & Cosmides, 1997). Briefly, the principles of Tooby & Cosmides’ paradigm are: 1) that the brain is a computer designed to generate behaviour appropriate to environmental circumstances; 2) that the neural circuits of the brain have been designed by natural selection; 3) that much of this circuitry is not available to the conscious mind; 4) that different neural circuits are modular, meaning that they are specialised for a particular task; and 5) that these brain circuits evolved to deal with conditions in an African savannah (Tooby & Cosmides, 1997). According to Pinker (1997), if a brain mechanism satisfies these criteria, it is likely to be evolved.

**B.3.2 Evaluating Pinker & Jackendoff and Hauser, Chomsky & Fitch**

The theoretical positions of both P&J and HCF are a result of limited knowledge about the workings of the human brain and even more limited knowledge of the history of human evolution. As a result, both positions have positives and negatives. As HCF argue, arguments about the evolutionary environment in which the species adapted are often speculation. As an example, it has been argued (e.g., Mithen, 2005) that Miller’s (2000; 2001) theory transplanted modern Western attitudes to music into the evolutionary environment. In contrast, it is widely held by most ethnomusicologists and cognitive psychologists that Western music and its manner of consumption is highly unusual cross-culturally and historically, and unlikely to resemble the music of 300,000 years ago or the manner in which that music was used (e.g., Blacking, 1973; Mithen, 2005). Furthermore, palaeontological evidence about
human evolution is notoriously difficult to interpret and new evidence and new techniques of analysis appear regularly, leading to rapid change of theoretical paradigms. For example, Mithen (2005) suggests that patterns of stress on bones imply that Neanderthals did indeed have descended larynxes, contrary to previous theories, and were capable of vocalizing in the same manner as modern humans. Fitch et al. (2005) are right to view such palaeontological evidence critically, as today’s theory may be shown to be tomorrow’s folly, especially as human palaeohistory is a fast-moving field with much recent evidence (Mithen, 2005). However, while there are problems involved in the use of archaeological evidence, this does not mean that this evidence should be dismissed outright. Under the criteria set out in Hauser et al. (2002), which ignore history, literacy might be seen as a likely adaptation by natural selection; the use of written symbols is unique to humans and appears to have specialised neural circuits. However, literacy is clearly not the result of adaptation; the first recorded evidence of the use of writing occurred only after the adoption of crop cultivation and pastoral techniques (Diamond, 1991), and large proportions of the world population today are still illiterate.

Additionally, as Jackendoff and Pinker (2005) point out, the criteria adopted by Hauser et al. (2002) lead to the assumption that language is optimally designed for the uses to which it is put today, whereas a theory about the evolution of language which incorporates knowledge about the history of evolution would predict that a brain mechanism like language is imperfect, and designed for a specific purpose for which it may or may not be currently used. Similarly, Pinker and Jackendoff (2005) argue that the criteria of Hauser et al. (2002) unjustly exclude brain mechanisms which are not unique to a particular domain – for example, the faculty for detecting melodic contours, which appears to be used in both music and language (e.g., Patel, Peretz, Labreque, & Tramo, 1998) – from the possibility that they may be evolved.

Additionally, Hauser et al. (2002) and Fitch et al. (2005), in a criterion that argues that a brain mechanism has to be unique to humans, include evidence from analogy as well as evidence from homology. For example, various crow species have the ability for episodic memory; these crows have the ability to remember not only where but when they hid caches of food, so that they do not return to caches which have spoiled. From this example they argue that episodic memory must not be part of FLN (Fitch et al., 2005), even though crows and humans almost certainly developed episodic
memory separately, for very different reasons. It may be that the development of episodic memory was an evolutionary motivation to the development of language in humans, and their criteria do not address this possibility.

**B.3.3 Justus and Hutsler (2005)**

A more nuanced, though still flawed, argument about the criteria necessary for arguing that a brain mechanism is an adaptation is that of Justus and Hutsler (2005). Justus and Hutsler (2005) argue that both the Tooby and Cosmides (1997) approach and the Hauser et al. (2002) approach are flawed, especially in relationship to the evolutionary status of music. They argue that theories of evolutionary psychology of music based on Tooby & Cosmides’ (1997) approach are flawed because they load the dice in favour of adaptation; such theories put the onus of proof on disproving the presence of the adaptation. As Justus & Hutsler (2005) point out, and the earlier example of literacy illustrates, humans are capable of transferring complex behaviours which give them an adaptive advantage through cultural transmission. While human culture is obviously based on biology and evolved capacities, human cultural knowledge is not necessarily adaptive. As such, a more agnostic approach to the possibility of evolutionary adaptations is appropriate.

Justus & Hutsler (2005) additionally argue that the distinction between the genotype and the phenotype is important. In regards to a behaviour, where the genotype refers to the genes written into an animal’s DNA and the phenotype is the expression of those genes, the original adaptiveness of that behaviour may no longer be expressed in the same way, especially in 21st Century Western culture, which is clearly a vastly different environment to the environment in which our ancestors evolved. Justus & Hutsler (2005) claim that many human behaviours are *exaptations*, where an evolutionary adaptation becomes used in ways which differ from the original evolutionary pressures acting upon that adaptation. However, they also argue that there is a continuum between exaptations and adaptations; according to Justus & Hutsler, there are also secondary adaptations, in which the genes behind an exaptation are modified by evolution in order to improve the evolutionary fitness of the exaptation. They argue that many behaviours and brain mechanisms are likely to be secondary adaptations; these adaptations are unlikely to fit criteria like that of Hauser
et al. (2002), which look for pure adaptations which are still used for their original purpose today.

**B.3.4 Evaluating Justus & Hutsler (2005)**

However, while their criticisms of other criteria are incisive, it is hard to see how the criteria of Justus & Hutsler (2005) could lead to the discovery of secondary adaptations. They nominate the following as their criteria for an evolutionary adaptation: Firstly that, for a particular cognitive domain, there are innate constraints; these may be *representational constraints* – predetermined neural patterns, *architectural constraints* – kinds of neurons found in certain areas of the cortex, and the ways in which brain areas connect with each other, and *chronotopic constraints* – constraints on the onset and offset of different developmental processes (i.e., that there are critical periods for the learning of a behaviour). Secondly, that there is domain specificity – according to Justus & Hutsler (2005) domain-general processes may have been evolved for a specific adaptive purpose, but we can never be sure of that purpose. According to Justus & Hutsler (2005), domain-specific processes – processes in which there is no parallel in other domains (for example, language) - provide the best evidence of an adapted brain mechanism or behaviour.

This is problematic for their theory. Though it is quite possible that some brain mechanisms are domain-specific, no human brain mechanisms - whether those involving music, language, visual perception or cheating mechanisms – have been conclusively proven to be domain-specific. For example, both Jackendoff & Pinker (2005) and Fitch et al. (2005) agree that the ability for recursion in language could be useful in problem solving, spatial navigation and social cognition, all of which may have existed before language, though Fitch et al. (2005) disagree that a shared brain module is responsible for all these things. Additionally, music is clearly recursive; even the meaning of exact repetitions changes with each repetition (Meyer, 1956), and it should be noted that the first performance of Erik Satie’s piece ‘Vexations’ took almost 19 hours (Ford, 1999); Lerdahl & Jackendoff (1993) generative theory of tonal music argues that music is recursive, with a hierarchical structure similar to that of speech. As there is widespread agreement that the human ability for language is
evolved, in some way, it is not clear that domain specificity is a worthwhile precondition for establishing that a human brain mechanism is an adaptation.

Additionally, from a theoretical rather than empirical perspective, Justus & Hutsler (2005) effectively divide a complex web of interactions between areas of the brain into what Sternberg (1989) calls a Mad Hatter’s question about domain-generality versus domain-specificity. Sternberg (1989) instead argues that there is a continuum between domain-generality and domain-specificity, and that completely domain-specific or domain-general cognitive domains are nonexistent. Furthermore, Atkinson and Wheeler (2004) argue that domain-general processes can be the result of evolution and may even be necessary for evolutionarily adapted cognitive processes to occur in a species. They discuss the ‘grain problem’, which is essentially a recognition that adaptive problems are typically hierarchical and nested; to Atkinson and Wheeler (2004), some adaptations might only be present at individual levels of organization within the hierarchy of a particular adaptive problem. For example, to extend an example given by Atkinson and Wheeler (2004), the problem of how to choose a suitable mate has several levels. At one level, it is a simple problem – is a particular person a good mate choice or not? At a lower level, it is made up of several problems that may oppose each other – is the person likely to have good reproductive prospects, is the person likely to be a good parent? And, at an even lower level, are good reproductive prospects a result of youth, healthiness, social status, etc? And, at a still lower level, how does one accurately measure healthiness, for example, considering that healthiness is an overall concept subsuming several different and often unrelated aspects of one’s physical state? And so on to ad infinitum. This is a problem for evolutionary theorists such as Justus and Hutsler (2005), who privilege domain-specific cognitive processes. That is, evolutionary theorists who privilege domain-specificity must either argue that every level of organization within a hierarchy of a cognitive domain is domain-specific, or they must argue that the process cannot be proved to be evolved, as some levels of it are domain-general. Furthermore, Atkinson and Wheeler (2004) argue that these domain-general features of the hierarchy are vital to the successful functioning of a particular cognitive domain; while recursion may or may not be the only part of language unique to humans, as Hauser et al. (2002) argue, the presence of recursion on its own is not the presence of the ability for language. Atkinson and Wheeler (2004) instead argue that a
more fruitful approach is to accept that components of different levels of organization within a hierarchy may be domain-general or domain-specific, and may have different adaptive evolutionary explanations which are equally as good as each other. As it appears that most cognitive domains utilise a mix of specific and general processes, Justus and Hutsler (2005) cannot logically argue that domain-specificity is a necessary criterion for proving that a cognitive process is an adaptation. However, Justus and Hutsler (2005) can, however, argue that the domain-specificity of a cognitive process is strong evidence that the process is an adaptation, given historical plausibility.

Some aspects of the levels of organization within the hierarchy of the cognitive domain involved in the perception and production of music are more domain-specific than others. For example, the cognition of melodic contour appears to be reliant on similar, if not identical, brain mechanisms to the cognition of prosodic contour (e.g., Patel et al., 1998) and may be specific to these particular tasks – though see Cupchik, Phillips, & Hill (2001), who argue that there is a link between melodic contour and spatial contour. In contrast, while people associate particular pieces of music with particular events in their lives, people seem to use episodic memory in a wide variety of cognitive domains completely unrelated to music. However, that the cognition of melodic contour is reliant on similar brain mechanisms to the cognition of prosodic contour does not mean that the cognition of melodic contour is not an adaptation, contrary to what Justus and Hutsler (2005) argue. Instead, it means that either the cognition of melodic contour or the cognition of prosodic contour could be an adaptation. Alternatively, there may be another explanation for the presence of that brain mechanism. For example, Cupchik et al. (2001) argued that there were shared processes between the cognition of spatial contour and the cognition of melodic contour, though methodological problems with their experimental design mean that their experimental manipulations of melodic contour do not reflect normal processing of melodic contour. In any case, it is possible that both the cognition of melodic contour and the cognition of prosodic contour may be exaptations freeloading off brain mechanisms originally adapted for the cognition of spatial contour. As another alternative, it may be that there have been secondary adaptations of a brain mechanism originally adapted for use in spatial cognition to make it more useful in the cognition of melodic contour or the cognition of prosodic contour. Another
possibility is that there may be shared processes between the cognition of melodic contour, the cognition of prosodic contour and the cognition of spatial contour, but also separate specific processes at different levels of organization of the hierarchy of the cognitive domain of music. While some of these possibilities may be more likely than others – especially considering the methodological issues with Cupchik et al. (2001) - the criteria of Justus and Hutsler (2005) restrict possible evolutionary arguments to those that argue that a cognitive mechanism is domain-specific, and therefore an adaptation, or is not domain-specific, and therefore not an adaptation. This effectively biases the criteria towards making Type II errors in order to avoid making Type I errors. In conclusion, Justus and Hutsler’s (2005) criteria of the presence of innate constraints are useful, but their criterion of domain-specificity is not as useful.
APPENDIX C. Notated Examples of Stimuli from Experiments 1a, 1b, and 2

The following melodies were used in the practice trials of Experiments 1a, 1b, and 2:

Figure C.1.1. Melody i542 with no alterations, in the key of C.

Figure C.1.2. Melody i542 with a step-to-leap alteration, in the key of E.

Figure C.1.3. Melody i542 with a contour & PIM alteration, in the key of E.

The following melodies were used in the experimental trials of Experiments 1a, 1b, and 2:

Figure C.2.1. Melody i502 with no alterations, in the key of C.

Figure C.2.2. Melody i502 with a contour alteration, in the key of E.
Figure C.2.3. Melody i502 with a step-to-leap alteration, in the key of E.

Figure C.2.4. Melody i502 with a leap-to-step alteration, in the key of E.

Figure C.2.5. Melody i502 with a contour + PIM alteration, in the key of E.

Figure C.3.1. Melody i505 with no alterations, in the key of C.

Figure C.3.2. Melody i505 with a contour alteration, in the key of E.

Figure C.3.3. Melody i505 with a step-to-leap alteration, in the key of E.

Figure C.3.4. Melody i505 with a leap-to-step alteration, in the key of E.

Figure C.3.5. Melody i505 with a contour + PIM alteration, in the key of E.
Figure C.4.1. Melody i515 with no alterations, in the key of C.

Figure C.4.2. Melody i515 with a contour alteration, in the key of E.

Figure C.4.3. Melody i515 with a step-to-leap alteration, in the key of E.

Figure C.4.4. Melody i515 with a leap-to-step alteration, in the key of E.

Figure C.4.5. Melody i515 with a contour + PIM alteration, in the key of E.

Figure C.5.1. Melody i518 with no alterations, in the key of C.

Figure C.5.2. Melody i518 with a contour alteration, in the key of E.

Figure C.5.3. Melody i518 with a step-to-leap alteration, in the key of E.
Figure C.5.4. Melody i518 with a leap-to-step alteration, in the key of E.

Figure C.5.5. Melody i518 with a contour + PIM alteration, in the key of E.

Figure C.6.1. Melody i545 with no alterations, in the key of C.

Figure C.6.2. Melody i545 with a contour alteration, in the key of E.

Figure C.6.3. Melody i545 with a step-to-leap alteration, in the key of E.

Figure C.6.4. Melody i545 with a leap-to-step alteration, in the key of E.

Figure C.6.5. Melody i545 with a contour + PIM alteration, in the key of E.

Figure C.7.1. Melody i549 with no alterations, in the key of C.
Figure C.7.2. Melody i549 with a contour alteration, in the key of E.

Figure C.7.3. Melody i549 with a step-to-leap alteration, in the key of E.

Figure C.7.4. Melody i549 with a leap-to-step alteration, in the key of E.

Figure C.7.5. Melody i549 with a contour + PIM alteration, in the key of E.

Figure C.8.1. Melody i551 with no alterations, in the key of C.

Figure C.8.2. Melody i551 with a contour alteration, in the key of E.

Figure C.8.3. Melody i551 with a step-to-leap alteration, in the key of E.

Figure C.8.4. Melody i551 with a leap-to-step alteration, in the key of E.
Figure C.8.5. Melody i551 with a contour + PIM alteration, in the key of E.

Figure C.9.1. Melody i554 with no alterations, in the key of C.

Figure C.9.2. Melody i554 with a contour alteration, in the key of E.

Figure C.9.3. Melody i554 with a step-to-leap alteration, in the key of E.

Figure C.9.4. Melody i554 with a leap-to-step alteration, in the key of E.

Figure C.9.5. Melody i554 with a contour + PIM alteration, in the key of E.

Figure C.10.1. Melody p779 with no alterations, in the key of C.

Figure C.10.2. Melody p779 with a contour alteration, in the key of E.
Figure C.10.3. Melody p779 with a step-to-leap alteration, in the key of E.

Figure C.10.4. Melody p779 with a leap-to-step alteration, in the key of E.

Figure C.10.5. Melody p779 with a contour + PIM alteration, in the key of E.

Figure C.11.1. Melody p788 with no alterations, in the key of C.

Figure C.11.2. Melody p788 with a contour alteration, in the key of E.

Figure C.11.3. Melody p788 with a step-to-leap alteration, in the key of E.

Figure C.11.4. Melody p788 with a leap-to-step alteration, in the key of E.

Figure C.11.5. Melody p788 with a contour + PIM alteration, in the key of E.
Figure C.12.1. Melody p850 with no alterations, in the key of C.

Figure C.12.2. Melody p850 with a contour alteration, in the key of E.

Figure C.12.3. Melody p850 with a step-to-leap alteration, in the key of E.

Figure C.12.4. Melody p850 with a leap-to-step alteration, in the key of E.

Figure C.12.5. Melody p850 with a contour + PIM alteration, in the key of E.

Figure C.13.1. Melody p871 with no alterations, in the key of C.

Figure C.13.2. Melody p871 with a contour alteration, in the key of E.

Figure C.13.3. Melody p871 with a step-to-leap alteration, in the key of E.
Figure C.15.2. Melody p946 with a contour alteration, in the key of E.

Figure C.15.3. Melody p946 with a step-to-leap alteration, in the key of E.

Figure C.15.4. Melody p946 with a leap-to-step alteration, in the key of E.

Figure C.15.5. Melody p946 with a contour + PIM alteration, in the key of E.

Figure C.16.1. Melody p968 with no alterations, in the key of C.

Figure C.16.2. Melody p968 with a contour alteration, in the key of E.

Figure C.16.3. Melody p968 with a step-to-leap alteration, in the key of E.

Figure C.16.4. Melody p968 with a leap-to-step alteration, in the key of E.
Figure C.16.5. Melody p968 with a contour + PIM alteration, in the key of E.

Figure C.17.1. Melody p1057 with no alterations, in the key of C.

Figure C.17.2. Melody p1057 with a contour alteration, in the key of E.

Figure C.17.3. Melody p1057 with a step-to-leap alteration, in the key of E.

Figure C.17.4. Melody p1057 with a leap-to-step alteration, in the key of E.

Figure C.17.5. Melody p1057 with a contour + PIM alteration, in the key of E.
APPENDIX D. Notated examples of stimuli from Experiments 3 and 4

The following melodies were used in the practice trials of Experiments 3 and 4:

![Figure D.1.1. Melody i1060 with no alterations in the key of C.](image1)

![Figure D.1.2. Melody i1060 with a metre alteration in the key of C.](image2)

The following melodies were used in the experimental trials of Experiments 3 and 4:

![Figure D.2.1. Melody i526 with no alterations in the key of C.](image3)

![Figure D.2.2. Melody i526 with a metre alteration in the key of C.](image4)

\[1\] Unfortunately, the program used to transcribe these melodies from the original MIDI files, Sibelius, appears to be unable to transcribe the addition of 7/12ths of a beat to a bar, and insisted on transcribing it as if it were instead lengthened by half a beat. These melodies have not been included in this appendix for this reason. Pulse alterations always occurred on the same note of a melody as the metre alterations; readers interested in the pulse alterations should infer from the metre alterations.
Figure D.3.1. Melody i527 with no alterations in the key of C.

Figure D.3.2. Melody i527 with a metre alteration in the key of C.

Figure D.4.1. Melody i529 with no alterations in the key of C.

Figure D.4.2. Melody i529 with a metre alteration in the key of C.

Figure D.4.1. Melody i558 with no alterations in the key of C.

Figure D.4.2. Melody i558 with a metre alteration in the key of C.

Unfortunately, the program used to transcribe these melodies from the original MIDI files, Sibelius, appears to be unable to transcribe the addition of 7/12ths of a beat to a bar, and insisted on transcribing it as if it were instead lengthened by half a beat. These melodies have not been included in this appendix for this reason. Pulse alterations always occurred on the same note of a melody as the metre alterations; readers interested in the pulse alterations should infer from the metre alterations.
Figure D.5.1. Melody i588 with no alterations in the key of C.

Figure D.5.2. Melody i588 with a metre alteration in the key of C.

Figure D.6.1. Melody i735 with no alterations in the key of C.

Figure D.6.2. Melody i735 with a metre alteration in the key of C.

Figure D.7.1. Melody i917 with no alterations in the key of C.

Figure D.7.2. Melody i917 with a metre alteration in the key of C.

Figure D.8.1. Melody i936 with no alterations in the key of C.

Unfortunately, the program used to transcribe these melodies from the original MIDI files, Sibelius, appears to be unable to transcribe the addition of 7/12ths of a beat to a bar, and insisted on transcribing it as if it were instead lengthened by half a beat. These melodies have not been included in this appendix for this reason. Pulse alterations always occurred on the same note of a melody as the metre alterations; readers interested in the pulse alterations should infer from the metre alterations.
Figure D.8.2. Melody i936 with a metre alteration in the key of C.\textsuperscript{4}

\textsuperscript{4} Unfortunately, the program used to transcribe these melodies from the original MIDI files, Sibelius, appears to be unable to transcribe the addition of 7/12ths of a beat to a bar, and insisted on transcribing it as if it were instead lengthened by half a beat. These melodies have not been included in this appendix for this reason. Pulse alterations always occurred on the same note of a melody as the metre alterations; readers interested in the pulse alterations should infer from the metre alterations.
APPENDIX E. Notated examples of stimuli from Experiments 5a and 5b

The following melodies were used in practice trials in Experiments 5a and 5b:

Figure E.1.1. Melody i823 with no alterations in the key of C.

Figure E.1.2. Melody i823 with a metre alteration in the key of C.\(^5\)

Figure E.1.3. Melody i823 with a contour alteration and a metre alteration in the key of C.

Figure E.1.4. Melody i823 with a PIM alteration and a metre alteration in the key of C.

\(^5\) Unfortunately, the program used to transcribe these melodies from the original MIDI files, Sibelius, appears to be unable to transcribe the addition of 7/12ths of a beat to a bar, and insisted on transcribing it as if it were instead lengthened by half a beat. These melodies have not been included in this appendix for this reason. Pulse alterations always occurred on the same note of a melody as the metre alterations; readers interested in the pulse alterations should infer from the metre alterations.
The following melodies were used in experimental trials in Experiments 5a and 5b:

*Figure E.2.1. Melody i526 with no alterations in the key of C.*

*Figure E.2.2. Melody i526 with a metre alteration and contour alteration in the key of C.*

*Figure E.2.3. Melody i526 with a metre alteration in the key of C.*

*Figure E.3.1. Melody i527 with no alterations in the key of C.*

*Figure E.3.2. Melody i527 with a metre alteration in the key of C.*

*Figure E.3.3. Melody i527 with a contour alteration in the key of C.*

Unfortunately, the program used to transcribe these melodies from the original MIDI files, Sibelius, appears to be unable to transcribe the addition of 7/12ths of a beat to a bar, and insisted on transcribing it as if it were instead lengthened by half a beat. These melodies have not been included in this appendix for this reason. Pulse alterations always occurred on the same note of a melody as the metre alterations; readers interested in the pulse alterations should infer from the metre alterations.
Figure E.3.4. Melody i527 with a PIM alteration in the key of C.

Figure E.3.5. Melody i527 with a contour alteration and metre alteration in the key of C.

Figure E.3.6. Melody i527 with a PIM alteration and a metre alteration in the key of C.

Figure E.4.1. Melody i529 with no alterations in the key of C.

Figure E.4.2. Melody i529 with a metre alteration in the key of C.

Figure E.4.3. Melody i529 with a contour alteration in the key of C.

Figure E.4.4. Melody i529 with a PIM alteration in the key of C.

Unfortunately, the program used to transcribe these melodies from the original MIDI files, Sibelius, appears to be unable to transcribe the addition of 7/12ths of a beat to a bar, and insisted on transcribing it as if it were instead lengthened by half a beat. These melodies have not been included in this appendix for this reason. Pulse alterations always occurred on the same note of a melody as the metre alterations; readers interested in the pulse alterations should infer from the metre alterations.
Figure E.4.5. Melody i529 with a contour alteration and metre alteration in the key of C.\textsuperscript{8}

Figure E.4.6. Melody i529 with a PIM alteration and a metre alteration in the key of C.

Figure E.5.1. Melody i558 with no alterations in the key of C.

Figure E.5.2. Melody i558 with a metre alteration in the key of C.

Figure E.5.3. Melody i558 with a contour alteration in the key of C.

Figure E.5.4. Melody i558 with a PIM alteration in the key of C.

Figure E.5.5. Melody i558 with a contour alteration and metre alteration in the key of C.

\textsuperscript{8} Unfortunately, the program used to transcribe these melodies from the original MIDI files, Sibelius, appears to be unable to transcribe the addition of 7/12ths of a beat to a bar, and insisted on transcribing it as if it were instead lengthened by half a beat. These melodies have not been included in this appendix for this reason. Pulse alterations always occurred on the same note of a melody as the metre alterations; readers interested in the pulse alterations should infer from the metre alterations.
Figure E.5.6. Melody i558 with a PIM alteration and a metre alteration in the key of C.

Figure E.6.1. Melody i588 with no alterations in the key of C.

Figure E.6.2. Melody i588 with a metre alteration in the key of C.⁹

Figure E.6.3. Melody i588 with a contour alteration in the key of C.

Figure E.6.4. Melody i588 with a PIM alteration in the key of C.

Figure E.6.5. Melody i588 with a contour alteration and metre alteration in the key of C.

Figure E.6.6. Melody i588 with a PIM alteration and a metre alteration in the key of C.

⁹ Unfortunately, the program used to transcribe these melodies from the original MIDI files, Sibelius, appears to be unable to transcribe the addition of 7/12ths of a beat to a bar, and insisted on transcribing it as if it were instead lengthened by half a beat. These melodies have not been included in this appendix for this reason. Pulse alterations always occurred on the same note of a melody as the metre alterations; readers interested in the pulse alterations should infer from the metre alterations.
Figure E.7.1. Melody i785 with no alterations in the key of C.

Figure E.7.2. Melody i785 with a metre alteration in the key of C. ¹⁰

Figure E.7.3. Melody i785 with a contour alteration in the key of C.

Figure E.7.4. Melody i785 with a PIM alteration in the key of C.

Figure E.7.5. Melody i785 with a contour alteration and metre alteration in the key of C.

Figure E.7.6. Melody i785 with a PIM alteration and a metre alteration in the key of C.

Figure E.8.1. Melody i917 with no alterations in the key of C.

¹⁰ Unfortunately, the program used to transcribe these melodies from the original MIDI files, Sibelius, appears to be unable to transcribe the addition of 7/12ths of a beat to a bar, and insisted on transcribing it as if it were instead lengthened by half a beat. These melodies have not been included in this appendix for this reason. Pulse alterations always occurred on the same note of a melody as the metre alterations; readers interested in the pulse alterations should infer from the metre alterations.
Figure E.8.2. Melody i917 with a metre alteration in the key of C.

Figure E.8.3. Melody i917 with a contour alteration in the key of C.

Figure E.8.4. Melody i917 with a PIM alteration in the key of C.

Figure E.8.5. Melody i917 with a contour alteration and metre alteration in the key of C.

Figure E.8.6. Melody i917 with a PIM alteration and a metre alteration in the key of C.

Figure E.9.1. Melody i936 with no alterations in the key of C.

Figure E.9.2. Melody i936 with a metre alteration in the key of C.  

Figure E.9.3. Melody i936 with a contour alteration in the key of C.

Unfortunately, the program used to transcribe these melodies from the original MIDI files, Sibelius, appears to be unable to transcribe the addition of 7/12ths of a beat to a bar, and insisted on transcribing it as if it were instead lengthened by half a beat. These melodies have not been included in this appendix for this reason. Pulse alterations always occurred on the same note of a melody as the metre alterations; readers interested in the pulse alterations should infer from the metre alterations.
Figure E.9.4. Melody i936 with a PIM alteration in the key of C.

Figure E.9.5. Melody i936 with a contour alteration and metre alteration in the key of C.\(^\R\)

Figure E.9.6. Melody i936 with a PIM alteration and a metre alteration in the key of C.

\(^\R\)Unfortunately, the program used to transcribe these melodies from the original MIDI files, Sibelius, appears to be unable to transcribe the addition of 7/12ths of a beat to a bar, and insisted on transcribing it as if it were instead lengthened by half a beat. These melodies have not been included in this appendix for this reason. Pulse alterations always occurred on the same note of a melody as the metre alterations; readers interested in the pulse alterations should infer from the metre alterations.
APPENDIX F. Statistical Analyses

E.1 EXPERIMENT 1A WinPsy Output

Number of Groups: 2
Number of Measurements: 8

Number of subjects in...
Group 1: 20
Group 2: 19

Between contrast coefficients
Contrast     Group...
            1  2
B1           1 -1

Within contrast coefficients
Contrast     Measurement...
            1  2  3  4  5  6  7  8
LEAP_SvL     W1  0  1  0  0  0 -1  0  0
STEP_SvL     W2  0  0  1  0  0  0 -1  0
MELC_SvL     W3  1  0  0  0 -1  0  0  0
PIMC_SvL     W4  0  0  0  1  0  0  0 -1
SH_PIMCvMC   W5 -1  0  0  1  0  0  0  0
SH_PIMCvLEAP W6  0 -1  0  1  0  0  0  0
SH_PIMCvSTEP W7  0  0 -1  1  0  0  0  0
LO_PIMCvMC   W8  0  0  0  0 -1  0  0  1
LO_PIMCvLEAP W9  0  0  0  0  0 -1  0  1
LO_PIMCvSTEP W10  0  0  0  0  0  0 -1  1
LEAPvSTEP    W11  0  1 -1  0  0  1 -1  0

Means and Standard Deviations
Group 1 Overall Mean: 0.341
Measurement      1  2  3  4  5
6  7  8
Mean            0.442 0.423 0.273 0.555 0.262
0.341 0.098 0.333
SD              0.307 0.233 0.273 0.247 0.200
0.297 0.187 0.374

Group 2 Overall Mean: 0.439
Measurement      1  2  3  4  5
6  7  8
Mean            0.643 0.446 0.360 0.650 0.313
0.464 0.118 0.516
SD              0.175 0.209 0.248 0.225 0.205
0.237 0.210 0.256

Means and SDs averaged across groups
Measurement      1  2  3  4  5
6  7  8
<table>
<thead>
<tr>
<th>Mean</th>
<th>0.543</th>
<th>0.435</th>
<th>0.317</th>
<th>0.602</th>
<th>0.288</th>
</tr>
</thead>
<tbody>
<tr>
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### Analysis of Variance Summary Table

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### Bonferroni 95% Simultaneous Confidence Intervals

The CIs refer to mean difference contrasts, with coefficients rescaled if necessary. The rescaled contrast coefficients are:

Rescaled Between contrast coefficients

| Contrast | Group... |
### Rescaled Within contrast coefficients

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### Raw CIs (scaled in Dependent Variable units)

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Approximate Standardized CIs (scaled in Sample SD units)

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**E.2 EXPERIMENT 1B WinPsy Output**

### E.2.1 Hit Rate compared to False Alarm Rate

Number of Groups: 1  
Number of Measurements: 10

Number of subjects in...  
Group 1: 19

Within contrast coefficients

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Means and Standard Deviations  
Group 1  Overall Mean: 0.420
### Measurement Data

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<tr>
<td>Mean</td>
<td>0.259</td>
<td>0.388</td>
<td>0.336</td>
<td>0.289</td>
<td>0.493</td>
</tr>
<tr>
<td>0.507</td>
<td>0.489</td>
<td>0.414</td>
<td>0.451</td>
<td>0.579</td>
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<tr>
<td>SD</td>
<td>0.135</td>
<td>0.161</td>
<td>0.225</td>
<td>0.187</td>
<td>0.281</td>
</tr>
<tr>
<td>0.145</td>
<td>0.186</td>
<td>0.171</td>
<td>0.214</td>
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### Means and SDs Averaged Across Groups

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<tr>
<td>Mean</td>
<td>0.259</td>
<td>0.388</td>
<td>0.336</td>
<td>0.289</td>
<td>0.493</td>
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<td>0.507</td>
<td>0.489</td>
<td>0.414</td>
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<td>0.161</td>
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<td>0.281</td>
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<td>0.171</td>
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### Analysis of Variance Summary Table

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<td>Within</td>
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<td>Error</td>
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### Bonferroni 95% Simultaneous Confidence Intervals

The CIs refer to mean difference contrasts, with coefficients rescaled if necessary.

The rescaled contrast coefficients are:

### Rescaled Within Contrast Coefficients

<table>
<thead>
<tr>
<th>Contrast</th>
<th>Measurement...</th>
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<th>6</th>
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<th>10</th>
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<tr>
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<td>LEAPHRvSHORT W2</td>
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<td>0.000</td>
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<tr>
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<td>PIMCHRvSHORT W4</td>
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340
CONHRvLONGFA W5  0.000  0.000  0.000  0.000  0.000  
0.000  -1.000  1.000  0.000  0.000  0.000  
LEAPHRvLONGF W6  0.000  0.000  0.000  0.000  0.000  
0.000  -1.000  1.000  0.000  0.000  0.000  
STEPHRvLONGF W7  0.000  0.000  0.000  0.000  0.000  
0.000  -1.000  0.000  0.000  1.000  0.000  
PIMCHRvSHORT W8  0.000  0.000  0.000  0.000  0.000  
0.000  -1.000  0.000  0.000  0.000  1.000  

<table>
<thead>
<tr>
<th>Contrast</th>
<th>Value</th>
<th>SE</th>
<th>Lower</th>
<th>Upper</th>
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<tbody>
<tr>
<td>CONHRvSHORTF W1</td>
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<td>0.042</td>
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<tr>
<td>LEAPHRvSHORT W2</td>
<td>0.076</td>
<td>0.046</td>
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<tr>
<td>STEPHRvSHORT W3</td>
<td>0.030</td>
<td>0.048</td>
<td>-0.119</td>
<td>0.179</td>
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<tr>
<td>PIMCHRvSHORT W4</td>
<td>0.234</td>
<td>0.066</td>
<td>0.029</td>
<td>0.439</td>
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<tr>
<td>CONHRvLONGFA W5</td>
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<td>0.059</td>
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<td>-0.281</td>
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<tr>
<td>STEPHRvLONGF W7</td>
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<tr>
<td>PIMCHRvSHORT W8</td>
<td>0.072</td>
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Approximate Standardized CIs (scaled in Sample SD units)

<table>
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<tr>
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<th>Value</th>
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<th>Lower</th>
<th>Upper</th>
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</thead>
<tbody>
<tr>
<td>CONHRvSHORTF W1</td>
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<tr>
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<td>STEPHRvSHORT W3</td>
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<tr>
<td>PIMCHRvSHORT W4</td>
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<tr>
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<td>0.303</td>
<td>-1.031</td>
<td>0.846</td>
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<td>LEAPHRvLONGF W6</td>
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<td>0.313</td>
<td>-1.451</td>
<td>0.489</td>
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<tr>
<td>STEPHRvLONGF W7</td>
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<td>0.374</td>
<td>0.297</td>
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**E.2.2 Hit Rate minus False Alarm Rate.**

Number of Groups: 1  
Number of Measurements: 8  
Number of subjects in...  
Group 1: 19  
Within contrast coefficients

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<td></td>
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<tr>
<td>SH_LEAPvPIMC W1</td>
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<tr>
<td>SH_STEPvPIMC W2</td>
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<tr>
<td>LO_LEAPvPIMC W3</td>
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<tr>
<td>LO_STEPvPIMC W4</td>
<td>0</td>
</tr>
<tr>
<td>STEP_SHvLO W5</td>
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<tr>
<td>LEAP_SHvLO W6</td>
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</tr>
</tbody>
</table>
CON_SHvLO  W7  1  0  0  0  -1  0  0  0
LO_LEAPvPIMC W8  0  0  0  0  0  -1  0  1

Means and Standard Deviations
Group 1 Overall Mean:  0.080
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<td>0.076</td>
<td>0.030</td>
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<td>0.048</td>
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<tr>
<td>SD</td>
<td>0.185</td>
<td>0.201</td>
<td>0.210</td>
<td>0.289</td>
<td>0.188</td>
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<tr>
<td>Mean</td>
<td>0.129</td>
<td>0.076</td>
<td>0.030</td>
<td>0.234</td>
<td>0.048</td>
</tr>
<tr>
<td>SD</td>
<td>0.185</td>
<td>0.201</td>
<td>0.210</td>
<td>0.289</td>
<td>0.188</td>
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Means and SDs averaged across groups
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<th>4</th>
<th>5</th>
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</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.129</td>
<td>0.076</td>
<td>0.030</td>
<td>0.234</td>
<td>0.048</td>
</tr>
<tr>
<td>SD</td>
<td>0.185</td>
<td>0.201</td>
<td>0.210</td>
<td>0.289</td>
<td>0.188</td>
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</table>

Analysis of Variance Summary Table

<table>
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<tr>
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<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
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Within

<table>
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<th>MS</th>
<th>F</th>
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<td>0.004</td>
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<td>0.023</td>
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<td>0.260</td>
<td>9.075</td>
</tr>
<tr>
<td>Error</td>
<td>0.516</td>
<td>18</td>
<td>0.029</td>
<td></td>
</tr>
</tbody>
</table>

Bonferroni 95% Simultaneous Confidence Intervals

The CIs refer to mean difference contrasts, with coefficients rescaled if necessary.
The rescaled contrast coefficients are:

<table>
<thead>
<tr>
<th>Contrast</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
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<td>1</td>
</tr>
<tr>
<td>SH_LEAPvPIMC W1</td>
<td>0.000</td>
</tr>
<tr>
<td>LO_LEAPvPIMC W8</td>
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</tr>
</tbody>
</table>

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### E.3 EXPERIMENT 2 WinPsy Output

Number of Groups: 1
Number of Measurements: 16

Number of subjects in...
  Group 1: 28

Within contrast coefficients
Contrast | Measurement...  
<table>
<thead>
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<th></th>
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</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>11 12 13 14 15 16</td>
<td></td>
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<tr>
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<tr>
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<tr>
<td>SHORT_LTS_HR W3</td>
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</tr>
<tr>
<td>SHORT_CPIM_H W4</td>
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</tr>
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<td>LONG_CON_HRV W5</td>
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</tr>
<tr>
<td>LONG_STL_HRV W6</td>
<td>0 0 0 0 0 -1 0 0 0</td>
</tr>
<tr>
<td>LONG_LTS_HRV W7</td>
<td>0 0 0 0 0 0 -1 0 0</td>
</tr>
<tr>
<td>LONG_CPIM_HR W8</td>
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</tbody>
</table>

Means and Standard Deviations
Group 1 Overall Mean: 0.386
Measurement 1 2 3 4 5
| 6 7 8 9 10 11 |
|-----------|------------------|
| 12 13 14 15 16 |
| Mean | 0.366 0.393 0.246 0.406 0.473 |
| 0.451 0.388 0.397 0.321 0.326 0.366 |
| 0.406 0.459 0.429 0.372 0.372 |
| SD | 0.195 0.206 0.178 0.305 0.157 |
| 0.171 0.227 0.213 0.138 0.202 |
| 0.162 0.196 0.209 0.211 |

Means and SDs averaged across groups
Measurement 1 2 3 4 5
| 6 7 8 9 10 11 |
|-----------|------------------|
| 12 13 14 15 16 |
| Mean | 0.366 0.393 0.246 0.406 0.473 |
| 0.451 0.388 0.397 0.321 0.326 0.366 |
| 0.406 0.459 0.429 0.372 0.372 |
| SD | 0.195 0.206 0.178 0.305 0.157 |
| 0.171 0.227 0.213 0.138 0.202 |
| 0.162 0.196 0.209 0.211 |

Analysis of Variance Summary Table
Source | SS  | df  | MS  | F  
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Bonferroni 95% Simultaneous Confidence Intervals

The CIs refer to mean difference contrasts, with coefficients rescaled if necessary. The rescaled contrast coefficients are:

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<th>Measurement...</th>
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Raw CIs (scaled in Dependent Variable units)  

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<tr>
<th>Contrast</th>
<th>Value</th>
<th>SE</th>
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<th>Upper</th>
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<tbody>
<tr>
<td>SHORT_CON_HR W1</td>
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<td>0.078</td>
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<td>0.068</td>
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<tr>
<td>LONG_CON_HRv W5</td>
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<td>-0.137</td>
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<td>LONG_STL_HRv W6</td>
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Approximate Standardized CIs (scaled in Sample SD units)  

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<th>Upper</th>
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<tbody>
<tr>
<td>SHORT_CON_HR W1</td>
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<td>SHORT_CPM_H W4</td>
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**E.4 EXPERIMENT 3 WinPsy Output**

**E.4.1 Hit Rate compared to False Alarm Rate.**

Number of Groups: 2  
Number of Measurements: 3

Number of subjects in...  
Group 1: 17  
Group 2: 19

Between contrast coefficients  
Contrast Group...  
<table>
<thead>
<tr>
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<tr>
<td>B1</td>
<td>-1</td>
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<tr>
<td>1</td>
<td>2</td>
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Within contrast coefficients  
Contrast Measurement...  
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<tr>
<th>Contrast</th>
<th>Measurement</th>
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<tbody>
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<tr>
<td>NME_HRvFA</td>
<td>0 1 -1</td>
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Means and Standard Deviations

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Measurement 1 2 3</td>
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<tr>
<td>Mean 0.779 0.779 0.054</td>
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<tr>
<td>SD 0.214 0.214 0.083</td>
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</table>

<table>
<thead>
<tr>
<th>Group 2 Overall Mean: 0.482</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement 1 2 3</td>
</tr>
<tr>
<td>Mean 0.724 0.632 0.092</td>
</tr>
<tr>
<td>SD 0.262 0.293 0.104</td>
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</tbody>
</table>

Means and SDs averaged across groups

<table>
<thead>
<tr>
<th>Measurement 1 2 3</th>
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</thead>
<tbody>
<tr>
<td>Mean 0.752 0.705 0.073</td>
</tr>
<tr>
<td>SD 0.241 0.259 0.094</td>
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</table>

Analysis of Variance Summary Table

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<tr>
<th>Source</th>
<th>SS</th>
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<td>B1</td>
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<td>Within</td>
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<tr>
<td>MET_HrvFA</td>
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<tr>
<td>W1</td>
<td>8.262</td>
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<td>8.262</td>
<td>222.153</td>
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<tr>
<td>W2</td>
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Bonferroni 95% Simultaneous Confidence Intervals

The CIs refer to mean difference contrasts, with coefficients rescaled if necessary.

The rescaled contrast coefficients are:

Rescaled Between contrast coefficients

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<tr>
<th>Contrast</th>
<th>Group...</th>
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<tbody>
<tr>
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Rescaled Within contrast coefficients

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<tr>
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<td>1 2 3</td>
</tr>
<tr>
<td>MET_HrvFA</td>
<td>W1 1.000 0.000</td>
</tr>
<tr>
<td>NME_HrvFA</td>
<td>W2 0.000 1.000</td>
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Raw CIs (scaled in Dependent Variable units)

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<th>Value</th>
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<th>Lower CI limits</th>
<th>Upper CI limits</th>
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<tr>
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<td>0.050</td>
<td>-0.157</td>
<td>0.046</td>
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<td>-0.094</td>
<td>0.091</td>
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**E.4.2 Hit Rate minus False Alarm Rate.**

**Number of Groups:** 2  
**Number of Measurements:** 14

**Number of subjects in...**  
Group 1: 20  
Group 2: 17

**Between contrast coefficients**
- **Contrast** | **Group...**  
  - 1  
  - 2  
  - B1  
  - 1  
  - -1

**Within contrast coefficients**
- **Contrast** | **Measurement...**  
  - 1  
  - 2  
  - 3  
  - 4  
  - 5  
  - 6  
  - 7  
  - 8  
  - 9  
  - 10

**Means and Standard Deviations**
- **Group 1**  
  - Overall Mean: 0.251
### Measurements

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<td>12</td>
<td>13</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
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<tr>
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**Group 2 Overall Mean:** 0.362

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Means and SDs averaged across groups

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**Bonferroni 95% Simultaneous Confidence Intervals**

The CIs refer to mean difference contrasts, with coefficients rescaled if necessary.

The rescaled contrast coefficients are:

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### E.5 EXPERIMENT 4 WinPsy Output

#### E.5.1 Hit Rate compared to False Alarm Rate.

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Number of Measurements: 14

Number of subjects in...  
Group 1: 21

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Means and Standard Deviations  
Group 1 Overall Mean: 0.380

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<td>7</td>
<td>0.458 0.387 0.744 0.577 0.304</td>
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<td>8</td>
<td>0.077 0.250 0.214</td>
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<td>0.221 0.205 0.225 0.261 0.211</td>
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<td>0.093 0.227 0.143</td>
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Means and SDs averaged across groups

<table>
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</thead>
<tbody>
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<td>6</td>
<td>0.589 0.595 0.250 0.304 0.220</td>
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<td>0.458 0.387 0.744 0.577 0.304</td>
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<td>0.077 0.250 0.214</td>
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Analysis of Variance Summary Table

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Within

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Bonferroni 95% Simultaneous Confidence Intervals

The CIs refer to mean difference contrasts, with coefficients rescaled if necessary. The rescaled contrast coefficients are:

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Approximate Standardized CIs (scaled in Sample SD units)

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**E.5.2 Hit Rate minus False Alarm Rate.**

Number of Groups: 1
Number of Measurements: 8

Number of subjects in...
Group 1: 20

Within contrast coefficients

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<td>-1 1 0 0 0 0 0 0</td>
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Means and Standard Deviations

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<td>-0.094</td>
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<tr>
<td>SD</td>
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<td>0.269</td>
<td>0.261</td>
<td>0.202</td>
<td>0.258</td>
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Means and SDs averaged across groups

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<tr>
<td>Mean</td>
<td>0.369</td>
<td>0.363</td>
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<td>-0.094</td>
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<td>0.269</td>
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<td>0.258</td>
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Analysis of Variance Summary Table

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Bonferroni 95% Simultaneous Confidence Intervals

The CIs refer to mean difference contrasts, with coefficients rescaled if necessary.

The rescaled contrast coefficients are:

<table>
<thead>
<tr>
<th>Contrast</th>
<th>Measurement</th>
<th>1</th>
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<th>3</th>
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355
### EXPERIMENT 5A WinPsy Output

E.6 EXPERIMENT 5A WinPsy Output

Number of Groups: 1
Number of Measurements: 36

Number of subjects in...
Group 1: 19

Within contrast coefficients

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<th>CI limits Upper</th>
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E.6 EXPERIMENT 5A WinPsy Output
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Bonferroni 95% Simultaneous Confidence Intervals

The CIs refer to mean difference contrasts, with coefficients rescaled if necessary.
The rescaled contrast coefficients are:

Rescaled Within contrast coefficients

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Raw CIs (scaled in Dependent Variable units)
### E.7 EXPERIMENT 5B WinPsy Output.

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Number of Measurements: 36

Number of subjects in...
Group 1: 17

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Means and Standard Deviations
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Means and SDs averaged across groups

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Analysis of Variance Summary Table

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<td>Within</td>
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| MvPxs     | W1  | 0.276 | 1 | 0.276 | 7.115 |
|           | Error | 0.620 | 16 | 0.039 |
| M&P_SvL   | W2  | 1.297 | 1 | 1.297 | 15.375 |
|           | Error | 1.349 | 16 | 0.084 |
| MET&PUL_FvN | W3  | 0.773 | 1 | 0.773 | 7.361 |
|           | Error | 1.680 | 16 | 0.105 |

361
### Bonferroni 95% Simultaneous Confidence Intervals

The CIs refer to mean difference contrasts, with coefficients rescaled if necessary. The rescaled contrast coefficients are:

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**Raw CIs (scaled in Dependent Variable units)**

<table>
<thead>
<tr>
<th>Contrast</th>
<th>Value</th>
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<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>MvPxS</td>
<td>W1</td>
<td>0.074</td>
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<tr>
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<td>0.140</td>
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<tr>
<td>SAME_C&amp;PvN</td>
<td>W5</td>
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</tr>
<tr>
<td>M&amp;P_KvTxS</td>
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<td>-0.163</td>
</tr>
<tr>
<td>M&amp;P_CvP</td>
<td>W7</td>
<td>-0.033</td>
<td>0.034</td>
<td>-0.138</td>
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</table>

**Approximate Standardized CIs (scaled in Sample SD units)**

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<tr>
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<th>Value</th>
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<td>-0.115</td>
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### E.8 Reaction Time Data

The focus in this thesis is on accuracy, rather than reaction time, in discriminating melodies. This focus on accuracy had various motivations. Firstly, previous research using melody discrimination tasks (e.g., Dowling, 1978, 1991; Dowling & Bartlett, 1981; Dyson & Watkins, 1984; Jones & Ralston, 1991; Peretz, 1990) has tended to use accuracy as the dependent variable. In contrast, the research of Edworthy (1985a) used reaction time as the dependent variable. Edworthy (1985a) aside, accuracy data
are more informative than reaction time data in comparing the data from this experiment with that of previous experiments.

Secondly, the use of reaction time data in order to analyse the results of melody discrimination tasks may be problematic. As mentioned in Section 4.2, notes in a melody are not equivalent to words in a list, but instead have a series of relationships to nonadjacent notes based on syntactic structure and melodic expectancy profiles (Lerdahl & Jackendoff; Margulis, 2005; Patel, 1998). Changing one note in a melody is therefore changing the melody, rather than just changing that single note, as the expectancy profile of the melody and the syntactic structure of the melody is also likely to change. This is especially so for this series of experiments, if it is the case that the joint accent structure of a melody has some correlation with the syntactic structure of the melody, as M. R. Jones (1993) argues. The stimuli used in the present experiments involved changes to features of the melody – contour, PIM, note length – which Jones has argued to be part of the joint accent structure. Therefore, the changes made here are especially likely to alter the syntactic structure of the melody. Secondly, Schellenberg (1997) argues that, at a note to note level, steps are more expected than leaps, and changes to melodic contour are more expected than continuations of melodic contour. Margulis (2005) argues that melodic expectancy does not only operate at a note to note level, but tension and release is built up over the course of a melody; her model uses generally similar assumptions about notes as Schellenberg except with further comparisons of notes beyond the note to note level. Thus, the melody alterations used in this experiment change the expectancy profile of the melodies.

That the melody alterations used in the present experiments alter the syntactic structure and the expectancy profile of the melody is problematic for the interpretation of reaction time data. If a melody alteration changes the whole melody, rather than a single note, then it becomes difficult to determine the temporal point in the melody at which the melody change occurs – that is, is it more appropriate to define that point at which the changed note begins or at the point where the melody ends.

Thirdly, determining reaction time in Experiments 5a and 5b, in particular, is problematic. Section 10.4 discusses the difference between the results of Experiments
5a and 5b in terms of the difference between when a pitch change is apparent and when a temporal change is apparent; in these experiments a pitch alteration could be apparent immediately after the pitch alteration, whereas a temporal alteration would not be apparent until after it became clear that the note was longer than it was in the standard melody. Thus, in these melodies, a pitch alteration on the same note as a temporal alteration is likely to be apparent earlier than a temporal alteration. Additionally, if participants are judging by the interonset intervals between notes rather than by the length of individual notes, pulse alterations are likely to be apparent earlier than metre alterations. It is unclear in experiments like those in this thesis whether temporal alterations were judged by the interonset intervals or by the length of individual notes – indeed, this was being tested experimentally, in terms of alterations based on temporal length compared to alterations based on deviation from the temporal grid. As it is therefore plausible to measure reaction time to a melody discrimination task from the beginning of the changed note, rather than at the end of that changed note, then it is, again, difficult to determine the temporal point from which to measure the reaction time. Further research, possibly using gating tasks, may be worthwhile in determining the location of the most appropriate temporal point to measure reaction time data. Thus it is difficult to compare pulse alterations to metre alterations using reaction time; as this was a comparison of interest in Experiments 3, 4, 5a and 5b, it is inappropriate to use reaction time data to compare the discrimination of metre alterations and pulse alterations.

Thus, there were significant problems with the use of reaction time data in melody discrimination tasks such as those used here, and reaction time data was not analysed.
APPENDIX G. Information Sheets, Consent Forms and Background Questionnaires
Information Sheet

MARCS Auditory Lab, Bldg 5, Bankstown

Research Project – The Cognition of Melodic Contour

Dear participant,

Thank you for signing up for this experiment. This research project is investigating melodic contour - the ‘shape’ made by the ups and downs of a melody – which appears to be an important part of the way people process music, especially novel music. You will be asked to listen to a pair of melodies at a comfortable listening level and judge whether the second melody is the same or different to the first melody. The task will take about 45 minutes. Credit for participation in the experiment will be given in the normal way.

Data collected will not be identified with individuals and will be kept confidential. Results of the study will be reported in a PhD thesis, and will be written up as a journal article and a conference presentation.

Your participation in this experiment is voluntary and you are free to discontinue your participation at any time. Withdrawing from the experiment will not affect your future relationship with the University of Western Sydney. If you have any additional questions please feel free to ask the investigator. If you decide to participate please complete the attached consent form and questionnaire.

Thank you for your time.

Tim Byron,
Principal Researcher

Dr Kate Stevens
Supervisor
MARCS Auditory Laboratories
Phone: +61 2 9772 6324
Fax: +61 2 9772 6736
Email: kj.stevens@uws.edu.au
Web: http://www.uws.edu.au/marcas/

NOTE: This study has been approved by the University of Western Sydney Human Research Ethics Committee (HEC 05/116). If you have any complaints or reservations about the ethical conduct of this research, you may contact the Ethics Committee through the Research Ethics Officers (tel: 02 4570 1136). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Consent Form

Re: The Cognition of Melodic Contour

I ____________________________ (Please print your name) have decided to participate in the experiment. I have read and understood the information provided. Any additional questions I asked have been answered to my satisfaction.

__________________________ (Please sign your name)                          __________________________ Date

NOTE: This study has been approved by the University of Western Sydney Human Research Ethics Committee. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Ethics Committee through the Research Ethics Officers (tel: 02 47360883). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Questionnaire

Re: melodic contour experiment

Name:

Age:

Gender: Male/Female (Please circle one)

Do you have any hearing difficulties? Yes/No (Please circle one)
If yes, please comment:

Have you had any musical training? Yes/No (Please circle one)
If yes, please comment (e.g., How many years?; What instrument? Etc):

Do you have absolute/perfect pitch? (that is, can you name a note when you hear it?)
Yes/No

What language/languages do you speak (apart from English) and how proficient are you in this/these languages?

Are you left or right handed? Left/Right (Please circle one)
APPENDIX H. Guide to Data CD

The data CD included with this thesis contains the wav files used in Experiments 1a, 1b, 2, 3, 4, 5a, 5b, and in the Pilot Experiment described in Chapter 9. Additionally, it includes the rtf files in which the experiments were written in DMDX. There are thus five main directories on the CD.

In the directory ‘Exp1a1b2’ are the rtf files and wav files associated with Experiments 1a, 1b, and 2, as these experiments used identical stimuli. The rtf files are named by experiment, and the two stimuli sets used in each of these experiments are referred to with the suffix _x (e.g., the two stimuli sets used in Experiment 1a are Exp1a_1 and Exp1a_2). The wav files are named with the format abbbbed.wav; where a refers to whether the melody was an Irish or a German folk melody (i.e., I = Irish while P = German), bbb refers to the number of the melody as named on the Kernscores website (e.g., 0502), c refers to the key of the melody (i.e., A = in the key of A major, C = in the key of C major, and E = in the key of E major), and d refers to the kind of melody alteration (i.e., 1 = no alteration, 2 = contour alteration, 3 = step-to-leap alteration, 4 = leap-to-step alteration, and 5 = contour and PIM alteration).

In the directory ‘Exp3’ are the rtf files and wav files associated with Experiment 3. The rtf files are named exp3_x.rtf, where the suffix _x refers to the stimuli set. The wav files are named with the format abcccdde.wav; where a refers to the timbre used in the file (i.e., A = acoustic piano, E = electric piano), b refers to whether the melody was an Irish or a German folk melody (i.e., I = Irish while P = German), cccd refers to the number of the melody as named on the Kernscores website (e.g., 0785), c refers to the key of the melody (i.e., A = in the key of A major, C = in the key of C major, E = in the key of E major, X = in the key of Eb major, Y = in the key of F# major, and Z = in the key of Bb major), and d refers to the kind of melody alteration (i.e., 1 = no alteration, 2 = metre alteration, 3 = pulse alteration, 4 = contour alteration).
In the directory ‘Exp4’ are the rtf files and wav files associated with Experiment 4. The rtf file is named exp4.rtf; there was only one stimuli set. The wav files are named with the format abecccde.wav; where $a$ refers to the tempo of the melody (i.e., $S =$ slow, $N =$ normal, $F =$ fast), $b$ refers to whether the melody was an Irish or a German folk melody (i.e., $I =$ Irish while $P =$ German), $c$ refers to the number of the melody as named on the Kernscores website (e.g., 0785), $c$ refers to the key of the melody (i.e., $C =$ in the key of C major), and $d$ refers to the kind of melody alteration (i.e., $1 =$ no alteration, $2 =$ metre alteration, $3 =$ pulse alteration).

In the directory ‘Exp4pilot’ are the rtf files and wav files associated with the Pilot Experiment in Chapter 9 for Experiment 4. The rtf file is named tempopilot.rtf; there was only one stimuli set. The wav files are named with the format 588_xxx.wav, where 588 refers to the melody number of the melody from the Kernscores database used, and xxx refers to the tempo the melody was played at (e.g., 120 = 120 bpm and 165 = 165 bpm).

In the directory ‘Exps5a5b’ are the rtf files and wav files associated with Experiments 5a and 5b. The rtf files are named by experiment, and the suffic _x refers to the stimuli set. The wav files are named with the format aaaaabede.wav; where aaaa refers to the number of the melody as named on the Kernscores website (e.g., 0785), $b$ refers to the kind of pitch alteration (i.e., $N =$ no alteration, $C =$ contour alteration, $M =$ PIM alteration), $c$ refers to the kind of temporal alteration (i.e., $1 =$ no alteration, $2 =$ metre alteration, $3 =$ pulse alteration), $d$ refers to the tempo (i.e., $N =$ normal tempo, $F =$ fast tempo) and $e$ refers to the key (i.e., $C =$ in the key of C major, and $E =$ in the key of E major).