A MULTICOMPONENTIAL EXAMINATION OF TENNIS PLAYERS' EMOTIONAL RESPONSES TO MUSIC

A thesis submitted for the degree of Doctor of Philosophy

by

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ABSTRACT

The principal aim of this research programme was to examine multiple components of competitive tennis players' emotional responses to pre-performance music. To this end, four objectives were defined: First, to develop a grounded theory (Glaser & Strauss, 1967) of players' use of music to manipulate emotional state; second, to examine the impact of altering music tempo and intensity on players' affective and behavioural responses; third, to identify neural origins for these phenomena; and fourth, to elucidate the role of motoneuron excitability in behavioural responses observed. These objectives were realised in four interrelated studies. First, 14 players provided quantitative and qualitative interview, questionnaire, and diary data to detail their use of personally emotive music; a grounded theory and associated model were consequently developed to facilitate future research and practice. Participants used music to attain five broad emotional states, including *psyched-up*; this was associated with faster tempi and louder intensities (volumes). Study 2 was conceived to examine the effects of manipulating these variables on 54 players' affective and behavioural states, using measures based on Russell's (1980) affective circumplex and reaction times (RTs). Faster tempi elicited higher valence and arousal, loud intensity yielded higher arousal and shorter RTs; and higher arousal was associated with shorter RTs. Functional magnetic resonance imaging was utilised in Study 3 to identify neural bases for 12 participants' emotional responses to the same music manipulations; emotion-processing, visuomotor and sensorimotor structures were activated under high-arousal conditions. Transcranial magnetic stimulation and electromyography were used in Study 4 to investigate changes in 10 participants' corticospinal excitability as a result of listening to purposively selected music; optimised music elicited higher arousal and reduced corticospinal response latencies. The foremost contribution of this thesis is to show that music variables may be carefully selected and/or manipulated to maximise performance-facilitating emotional responses to music in tennis.

ACKNOWLEDGEMENTS

I have quite a large number of acknowledgements to make, of *significant others* in my PhD process. I am hesitant to put some before others, so I think that the best way I can do this is to put them in roughly chronological order – those whom I've known the longest come first!

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Finally, I would like to give some words of acknowledgement to myself. This isn't being conceited; it's more a recognition of that little bit of reserve that we human beings sometimes manage to dredge up from somewhere. It's easy to see things in a positive light at this point in time, but I don't intend to forget the times when I felt so very low. I've not been *taught* the dedication I gave to this little project (thought I'd get that word in, Lauren), nor is it completely innate – despite the drive for living that I have both inherited and learnt from my mum and dad. Life has a tendency to continue unabated, unhindered by the PhD process; and everything it has to throw at you must be dealt with along the way. Conceding never entered my mind, even at times when I felt "utterly overwhelmed" (C. Cushion, personal communication, some time in 2004), and that is why I am not ashamed to say that I'm intensely proud of myself right now. I'm also proud of the work I present in this thesis, which is as it should be. I did it, mate; RIP.

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CHAPTER 1: INTRODUCTION TO THE RESEARCH PROGRAMME

1.1 Statement of the Problem

In concluding *The Expression of the Emotions in Man and Animals*, Charles Darwin (1872/1999) wrote that,

> …the language of the emotions, as it has sometimes been called, is certainly of importance for the welfare of mankind. To understand, as far as is possible, the source or origin of the various expressions which may hourly be seen on the faces of the men around us, not to mention our domesticated animals, ought to possess much interest for us. From these several causes, we may conclude that the philosophy of our subject has well deserved the attention which it has already received from several excellent observers, and that it deserves still further attention, especially from any able physiologist. (p. 360)

From the extraordinarily insightful writings of Darwin, through the equally influential accounts of William James (1884) and Walter Cannon (1927), the subject of emotion has continued to captivate eminent researchers (Damasio, 2000; Ekman, Sorenson, & Friesen, 1969; Frijda, 1986; Izard, 1977; Lazarus, 1991; LeDoux, 1995; Levenson, 1994; Mandler, 1984; Oatley & Jenkins, 1996; Panksepp, 1994; Rolls, 2005; Russell, 1983; Schachter & Singer, 1962; R. E. Thayer, 1989; Tomkins, 1962; Turner & Ortony, 1992). Emotions can be described as "short-lived psychological-physiological phenomena that represent efficient modes of adaptation to changing environmental demands" (Levenson, 1994, p. 123); and recent evidence indicates that they are indeed evolutionarily adaptive and highly efficient, enabling a preconscious automated response to situations, which may bypass higher cortical involvement (Ohman, 2005).

Music can elicit intense emotional responses, as manifested in phenomenological (Gabrielsson, 2001; Rickard, 2004), behavioural (Sloboda, 1991) and neurophysiological

(Blood & Zatorre, 2001; Blood, Zatorre, Bermudez, & Evans, 1999; Menon & Levitin, 2005) data; and manipulation of properties of the music stimulus has been successfully used as a strategy to improve cognitive performance (Schellenberg, Nakata, Hunter, & Tamoto, 2007) and to evoke neural indices of superior sporting performance (Amezcua, Guevara, & Ramos-Loyo, 2005). People actively use music on a daily basis to create desired mood states (Saarikallio & Erkkilä, 2007; R. E. Thayer, Newman, & McClain, 1994); and contemporary developments in technology mean that they can control not only the availability of music in the home, car, gym, and other everyday environments (North, Hargreaves, & Hargreaves, 2004), but also a number of music parameters, such as tempo.

Music has also been used in sport and exercise to reduce perceptions of exertion (Potteiger, Schroeder, & Goff, 2000), to enhance work output (Atkinson, Wilson, & Eubank, 2004) and strength performance (Karageorghis, Drew, & Terry, 1996), and to optimise psychological state for performance (Pates, Karageorghis, Fryer, & Maynard, 2003). At the 2004 Olympic Games in Athens, Michael Phelps achieved eight medals, six of which were gold. Before each race, Phelps listened to music on a personal stereo while making his entrance and when on poolside awaiting officials' instructions. Reportedly, it is rap music that gets him into his optimal zone of functioning (cf. Hanin, 1995); alleged favourites include DMX's *Party Up* and MAC 10's *Connected for Life*. Media reports also suggest that music listening plays a key role in the pre-performance and training routines of elite tennis players such as Scotland's Andrew Murray, who has expressed a penchant for *The Black Eyed Peas* (Blackley, 2005).

Despite the compelling combination of anecdotal and empirical evidence for the capacity of music to elicit potentially performance-facilitating emotional responses, music listening as a pre-performance strategy has received limited research attention (e.g., Gluch, 1993; Karageorghis & Terry, 1997; Pates et al., 2003). Nonetheless, the increasing portability and versatility of contemporary music formats, for example MP3 technology, mean that music listening is an emotion/mood regulation strategy that is not only already accepted by many tennis players (Bishop, Karageorghis, & Loizou, in press), but one that can easily be incorporated into their training and competitive regimens.

1.2 Aims of the Research Programme

The aims of this research programme are manifold:

1. To develop a grounded theory and model of young tennis players' use of music to modulate their emotions; this will facilitate not only future research into this phenomenon, but also future practices.
2. To pinpoint sources of emotion in music that may elicit performance-facilitating emotional profiles in young tennis players, and to investigate their effects on performance, via triangulation of affective, behavioural, and physiological data.
3. To identify neural correlates of tennis players' affective and behavioural responses to researcher-selected pre-performance music.
4. To ascertain the role of corticospinal excitability in improved motor performance as a result of listening to music which has been purposively selected to elicit a performance-enhancing state based on foregoing observations.
5. To develop a theoretical model to illustrate potential pathways by which optimised music may modify affective and behavioural responses.
6. To assess affective responses to music listening throughout the research programme using measures based on Russell's (1980) original circumplex model, which it is anticipated will afford the opportunity to identify recurring patterns that may yield superior performance in tennis.

1.3 Overview of the Present Research Programme

The present programme of research fulfils a number of research needs. Primarily, it is acknowledged that the predominant approach to music listening in sport and exercise has been with music as an accompaniment to activity, not as a pre-performance emotion regulation strategy (e.g., Atkinson et al., 2004; Boutcher & Trenske, 1990; Elliott, Carr, & Savage, 2003; Karageorghis, Jones, & Low, 2006); this may be compounded by the fact that music listening is not permitted during performance in the majority of competitive sports, including tennis. However, listening to music during training is commonplace, as is the presence of music during changeovers at the US Open – a *Grand Slam* event on both the ATP and WTA Tours. Although music listening as a mood regulation strategy has received a modicum of empirical attention in recent years (Hewston, Lane, Karageorghis, & Nevill, 2004; Stevens & Lane, 2001), the potential of music listening to help a performer control more transient emotional states has not (see Beedie, Terry, & Lane, 2005, for a discussion of mood-emotion distinctions). Also, despite the fact that the affective tone of music can be ascertained within a matter of seconds (Bigand, Filipic, & Lalitte, 2005), it appears as though the neurophysiological response component may peak after 30 s of listening (Koelsch, Fritz, von Cramon, Müller, & Friederici, 2006). Therefore, it was deemed an informative step to examine the *residual* effects of emotional responses to music.

The measurement of emotion, mood, and emotional responses to music have attracted various methodological approaches (e.g., Baumgartner, Esslen, & Jäncke, 2006; Bigand et al., 2005; Izard, Dougherty, Bloxom, & Kotsch, 1974; McNair, Lorr, & Droppleman, 1971; Waterman, 1996; Webster & Weir, 2005), but the circumplex model and its variants provide expeditious means by which to assess not only affective states in sport (Edmonds, Mann, Tenenbaum, & Janelle, 2006), but also emotional responses to music (North & Hargreaves, 1997). Therefore, this model was used to gauge participants’ emotional responses throughout the present research programme, and was cross-referenced with categorical emotion descriptors, in addition to neurophysiological, electrophysiological, and behavioural data.

At the outset, an initial questionnaire was administered to 67 tennis players at an international tennis academy in southwest London, England, UK. The responses obtained were used to select 14 tennis players according to their potential informativeness; they were subsequently invited to participate in qualitative interviews designed to elucidate the antecedents, intermediaries, and consequences of their use of music to manipulate their emotional state. Quantitative data were also collected to supplement the qualitative data, because such a mixed-methods approach was likely to provide appropriate direction for the later stages of the programme. A process model of the players' use of music to modulate their emotional state was developed, to build upon Gluch's (1993) earlier work, and to provide a launch pad for future work, both within and beyond the present research programme.

Given that *action tendencies* (Frijda, 1987) are a fundamental component of emotional responses, and that music can elicit autonomic changes which accompany such adaptive responses (Nyklícek, Thayer, & Van Doornen, 1997), the effect of listening to musical selections on affective responding and a performance-related measure such as choice reaction time (CRT) was considered to be an area worthy of further investigation. Hence, in the second stage of the research programme, the effect of listening to variants of a researcher-selected music track on participants' affective, and behavioural responses was assessed; this was achieved using the Affect Grid (Russell, Weiss, & Mendelsohn, 1989), and CRT data, respectively. Heart rate data were also recorded throughout, to provide some measure of sympathetic activity.

Functional magnetic resonance imaging (fMRI) data suggest that music elicits specific responses in emotion-processing structures in the brain (Blood & Zatorre, 2001; Gosselin et al., 2006; Menon & Levitin, 2005), and J. F. Thayer and Faith (2001) argued that valence may represent the evaluative outcome necessary in order to decide whether to initiate an approach or withdrawal response (cf. Gray, 1994) and that arousal reflects the resource investment in that action tendency (cf. Frijda, 1987). Therefore, the third stage of the present research programme was conceptualised in order to examine the neurophysiological correlates of emotional responses during music listening, and during performance of an immediately ensuing CRT task, with the intention of identifying performance-facilitating patterning. The aim of the final stage of the present research programme was to confirm or refute the role of increased/decreased corticospinal excitability in improved motor performance, using purposively selected, optimised, music as a stimulus. Motor evoked potentials (MEPs) were elicited by transcranial magnetic stimulation (TMS), and compound motor action potentials were measured via electromyographic (EMG) recording to this end.

1.4 Operational Definitions

The terms defined below recur throughout this thesis, and/or they were considered potentially ambiguous; hence, their inclusion.

Affect: The subjective feeling component of an emotional response to a stimulus which is accessible to an individual's consciousness, possessing both valence (positive or negative; see below) and activation (strong or weak) (author's own definition; cf. Larsen & Diener, 1992).

Asynchronous music: Music accompanying physical activity whose rhythm does not correspond to that of the activity.

Emotion: A pattern of neural activation in anatomically diverse but functionally integrative cortical and subcortical nuclei that forms the bridge between perception of a personally significant stimulus (internal or external), and the subsequent adaptive or maladaptive response – which comprises affective, cognitive, behavioural, expressive and physiological components (author's own definition; cf. Panksepp, 1998).

Grounded theory: Theory derived from data which have been systematically gathered and analysed through the research process.

Harmony: The structure of music with respect to the composition and progression of chords.

Intensity: The volume or magnitude of sound, usually in a specified direction.

Melody: A succession of notes forming a distinctive sequence.

Mood: An enduring and diffuse emotional state, which frequently has no perceptible eliciting stimulus.

Multicomponential: Drawing upon multiple distinct but complementary data sources.

Pitch: The perception of the frequency of a musical note.

Synchronous music: Music accompanying physical activity whose rhythm corresponds to that of the activity.

Tempo: The speed at which a musical composition is played, measured in beats per minute (bpm).

Valence: The positive or negative "charge" associated with a particular physical or mental state, or a particular combination of these (Charland, 2005). This term will be used interchangeably with the term *pleasantness* in this thesis.

Visuomotor: Relating to or denoting the coordination of movement and visual perception by the brain (Soanes & Stevenson, 2003).

1.5 Original Contribution of the Research Programme

This research programme makes an original contribution to the extant literature on music listening in sport in a number of ways. First, the model developed in Study 1 will provide a template to elucidate the antecedents, intermediaries and emotional consequences of music listening in a sporting context, interpreted in the light of foregoing music emotion research (e.g., Scherer & Zentner, 2001; Sloboda & Juslin, 2001; J. F. Thayer & Faith, 2001);

this template hitherto did not exist. This model will serve as a framework for subsequent investigation in the present research programme, and it is anticipated that it will guide future researchers with an interest in this phenomenon. Second, this programme will establish a link between emotional responses to music and *subsequent* choice reaction time performance – a vital component of reactive sports performance, such as that required in the tennis return-of-serve scenario. Third, neural correlates for both the affective response to music and of subsequent CRT task performance will be identified; an elucidatory step which will provide a substantial platform for sport psychology music research in the 21st century. Finally, EMG data will be used to reveal changes in corticospinal excitability occurring as a result of listening to purposively selected pre-performance music; changes which it is anticipated will be accompanied by altered subjective arousal, indicating a potential practical value for such affective changes. Importantly, the triangulation of sources of information in the present programme of research (see Figure 1.1) will answer the call from music emotion researchers for multimodal investigation of emotional responses to music (e.g., Scherer & Zentner, 2001).

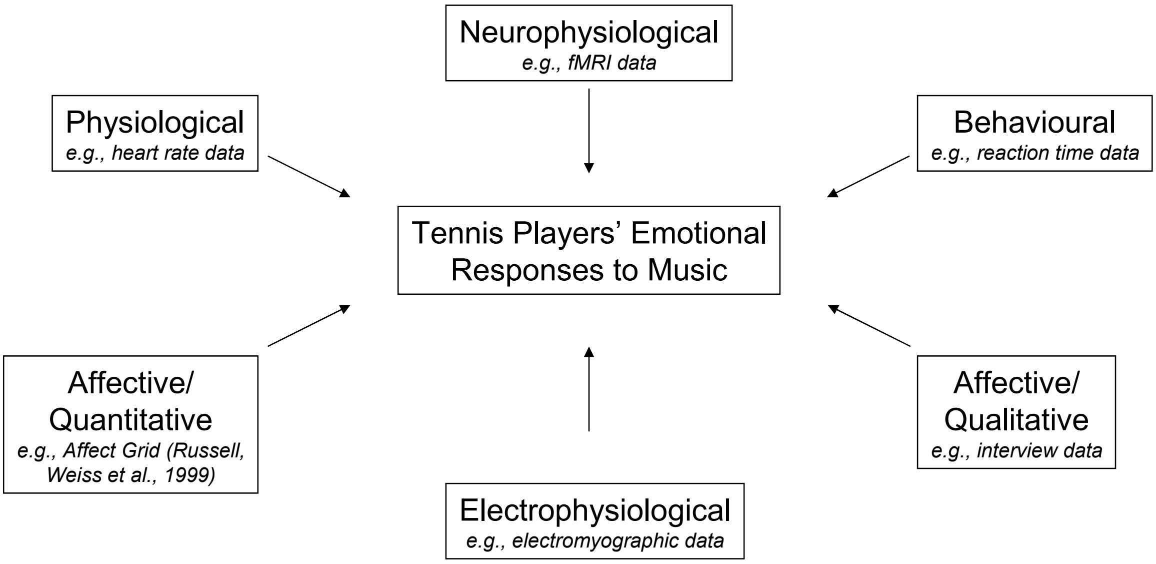

Figure 1.1. Triangulation of data sources in the investigation of competitive tennis players' emotional responses to music.

CHAPTER 2: REVIEW OF LITERATURE

This research programme investigated the efficacy of listening to music in order to manipulate emotions in young tennis players, via triangulation of multiple data sources. The *methodological eclecticism* (Hammersley, 1996) herein represents the author's pragmatic epistemological stance, and a belief that greater depth of knowledge comes through such triangulation. This eclecticism is reflected in the diversity of subject matter within this literature review, which covers the topics of emotion, mood, and affect; neurophysiology of emotion; emotions in sport; musically-induced emotional responses; the psychophysical effects of music on human performance; and methodological issues. This diversity in turn reflects the very novel nature of the area under investigation: The antecedents, intermediaries, and consequences of emotional responses to music within specific sporting contexts such as the tennis environment are presently under-researched. It is the author's intention that the conclusions drawn at the close of this thesis will be firmly couched within a framework of extant and present research; a framework which is suitably appraised in the following review.

2.1 Emotion

Despite the ubiquity of the term *emotion* in everyday parlance, the question of what constitutes an emotion has remained a point of discussion for over a century (Beedie, Terry, & Lane, 2005; James, 1884); everyone knows what an emotion is until asked to explain it. There is also some disagreement as to whether emotions possess functionality or instrumentality (Frijda, 1986; Keltner & Gross, 1999); the functionality of emotions and related affective constructs has subsequently been investigated in sport (Cerin, 2003). Regardless of their definition or perceived utility, widespread consensus exists that emotions are not only of evolutionary significance (Bradley & Lang, 2000; Erickson & Schulkin, 2003; Izard, 1993; Panksepp, 2000; Plutchik, 1980; R. E. Thayer, 1996), but also that they exist in all cultures and in some higher animals (Ekman & Friesen, 1986; Ortony & Turner, 1990).

The ability of humans to regulate them successfully enables them to cope effectively with the pressures of both everyday living and elite sport (Gould, Eklund, & Jackson, 1993; Gross, 1998; Lazarus, 1991, 1993, 2000, 2006).

2.1.1 *Emotion Theory: An Overview*

Following Darwin's (1872/1999) exposition of the evolutionary significance of emotions in humans, William James (1884) proposed that bodily changes, such as trembling and running away in response to seeing a bear, occur first and the perception of the emotion (in this example, fear) occurs as a consequence. Carl Lange (1885) later proposed a subtle variation on James's thesis, implicating autonomic, not somatic, feedback as the generator of the same emotional percepts. Thus, the James-Lange theory (James, 1884; Lange, 1885) of emotion was born. Walter Cannon (1927) identified major flaws in this theory, highlighting the relatively insensitivity and sluggishness of visceral structures in responding. He showed that artificial disruption of the visceral changes typical of certain strong emotions did not abolish those emotions. Phillip Bard (1928) modified Cannon's (1927) thesis: The Cannon-Bard (1931) theory identified subcortical origins of emotional responses, arguing that the sensation of emotions occurred only after higher cortical involvement; emotion occurs prior to the behavioural consequences and bodily sensations, (e.g., we feel fear then run away).

Other problems with the James-Lange (James, 1884; Lange, 1885) theory have since been identified. First, visceral and somatic changes induced during emotional experiences are not sufficient to differentiate between the subtle variations in emotional states we experience (Oatley & Jenkins, 1996). Second, when emotions are internally elicited, the peripheral changes are dramatically reduced by comparison to those elicited by external stimuli (Ekman, Levenson, & Friesen, 1983; Levenson, Ekman, & Friesen, 1990; Stemmler, 1989). Third, when autonomic changes are elicited by physiological intervention, the expected emotions are not produced. Schachter and Singer (1962) thus implicated the role of cognition in determining emotional responses; potentially emotive stimuli – whether internal or external – must first be evaluated or appraised.

Appraisal theory has been propagated by a number of researchers (Frijda, 1986; Izard, 1993; Lazarus, 1991; Oatley & Johnson-Laird, 1987; Scherer, 1999), and it acknowledges the pivotal role of cognitive evaluation of a stimulus in eliciting an emotional response. In their attempt to derive an operational definition of an emotion, Oatley and Jenkins (1996) concluded the following:

> An emotion is usually caused by a person consciously or unconsciously evaluating an event as relevant to a concern (a goal) that is important; the emotion is felt as positive when a concern is advanced and negative when a concern is impeded. (p. 96)

Despite being predominantly an appraisal theorist, Izard (1993) proposed four systems for activation of emotions, which collectively comprise both cognitive and non-cognitive processes. These four hierarchically arranged systems roughly correspond to evolutionary levels of development: Neural systems, which maintain the overall affective backdrop, such as positive or negative emotionality; sensorimotor systems, which facilitate early infant-mother interactions; motivational systems that activate emotions when homeostasis is sufficiently disturbed or result from one emotion activating another, to increase one's behavioural alternatives; and cognitive systems, which activate via appraisal, comparison, categorisation, or other judgements of interoceptive (internal sensory receptor) or exteroceptive (external sensory receptor) input. Subsequent developments in neuroscience lend strong support to the concept of hierarchical neural emotion systems (Adolphs, Tranel, & Damasio, 2003; Berridge, 2003; Davidson, 2003; Erickson & Schulkin, 2003; LeDoux, 1992, 1995, 1996; Ohman, 2005; Panksepp, 1998; Rolls, 2005).

2.1.2 *Primary and Secondary Emotions*

In their attempts to categorise emotions, a number of authors propose the concept of *primary* (Damasio, 1994) or *basic* (Izard, Dougherty, Bloxom, & Kotsch, 1974; Ortony & Turner, 1990) emotions, although the precise makeup of this class of emotions has been the subject of much debate (Ekman, 1992a, 1999a; Izard, 1992; Ortony & Turner, 1990; Panksepp, 1992; T. J. Turner & Ortony, 1992). For example, Damasio (2000) postulated the existence of six primary emotions, *happiness*, *sadness*, *fear*, *anger*, *surprise*, and *disgust*; while Izard (1971) had earlier suggested a more diverse array that included *contempt*, *distress*, *guilt*, *interest*, *joy*, and *shame*. However, a common underlying thread in all definitions is the implication of an innate or *hard-wired* set of adaptive responses to the environment; emotions have the ability to strip away the layers of acculturation, sophistication, and a lifetime of individualised learning, to produce the lowest common denominator of human response (Levenson, 1994). Nonetheless, it should be acknowledged at this point that these primitive responses may not always be adaptive in our contemporary multifaceted environment, with its highly complex interactions.

More recent accounts incorporate the concept of consciousness in defining levels of affective processes. If one assumes an evolutionarily adaptive role for emotions, then one must consider the undeniable role of consciousness in both eliciting and modifying emotions (Damasio, 2000; Edelman & Tononi, 2000; Macphail, 1998; Tononi & Edelman, 1998). The idea that affective states can be borne out of deliberative thought, unconscious immediate responding, or a combination of the two, continues to be of interest to researchers; their interaction – and coexistence – remains a hot topic in emotion research (Barrett, 2005; Barrett, Niedenthal, & Winkielman, 2005; Charland, 2005; Scherer, 2005).

Panksepp (1994a) appeared to imply differing levels of consciousness when delineating three levels of complexity for affective states: *Category 1* emotions are low-level, almost reflexive, primary emotional responses such as disgust in response to noxious substances, and probably serve important survival functions. *Category 2* emotions reflect integrated two-way communication between sensory and perceptual neural mechanisms and their motor counterparts. Panksepp suggests that these provide for adaptive behavioural and physiological changes which continue far beyond the foregoing causal stimulus, arguably representing some degree of experiential learning. Thus, Category 2 emotions may be described as moderately reflective primary emotions. *Category 3* emotions represent higher feelings, which remain chiefly internalised as subjective states. Therefore, these are only presently accessible to researchers by the use of traditional affective measures. Ergo, they are measurable only in humans.

Panksepp's (1994a) final class of emotions may represent what Damasio (2000) termed *secondary* or *social* emotions; relatively novel phenomena in evolutionary terms, which stem from greater involvement of frontal cortices during conscious deliberate contemplation of a situation or event. Damasio's (1994) diagrammatic representation of the mechanisms of primary and secondary emotions can be seen in Figure 2.1a and Figure 2.1b; the thick perimeter line represents the brain and brainstem. Damasio describes what he terms nature's "tinkering style of engineering" (p. 137), whereby intermediary emotion pathways make use of pre-existing (primitive) emotion machinery in order to create completely novel organismic responses. In the case of primary emotions, a stimulus activates the amygdala, a key emotion-processing centre of the brain (LeDoux, 1992), leading to internal responses (IR) and responses to neurotransmitter nuclei and the hypothalamus (H). The hypothalamus initiates endocrine and other chemical responses which effect their roles via the blood stream. In secondary emotions, the stimulus may still exert its effects directly, via the amygdala, but may also activate ventromedial cortex (VM), an area of somewhat primitive cortex in which emotions are processed. Thus, secondary emotions utilise the core machinery of primary emotions, but subsequent developments (in this instance the VM pathway) are allied to the pre-existing mechanism.

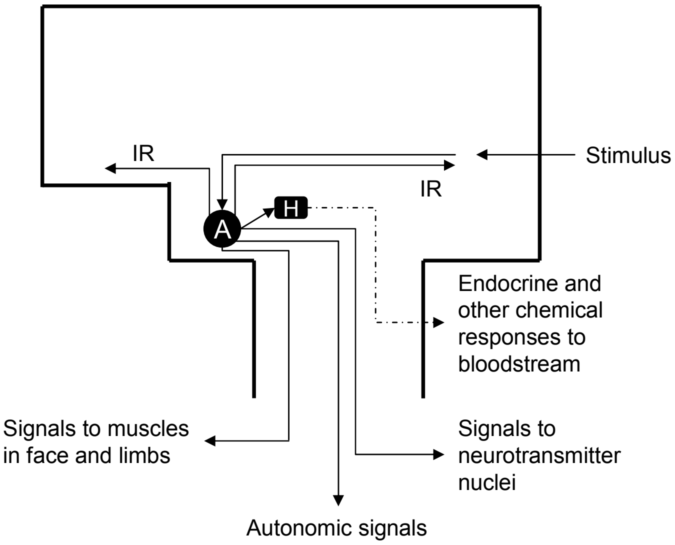

Figure 2.1a. A simplified mechanism of primary emotions (adapted from Damasio, 1994).

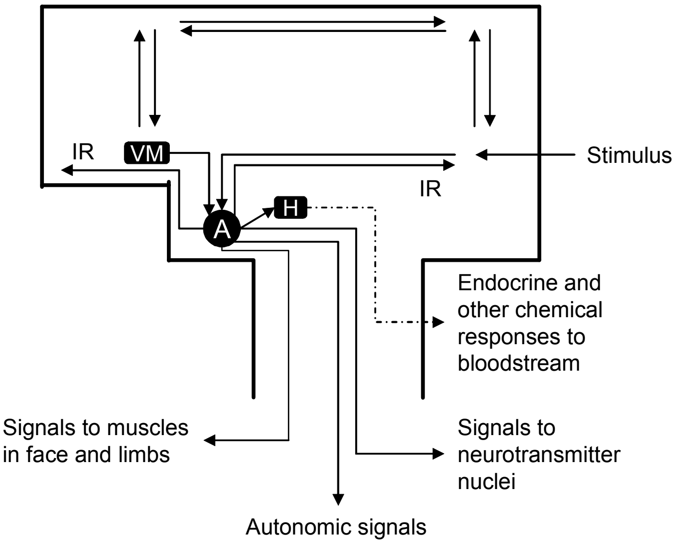

Figure 2.1b. A simplified mechanism of secondary emotions (adapted from Damasio, 1994).

While Damasio (1994) asserted secondary emotions to be founded on primary/fundamental emotions, others suggest that they are *blends* of basic emotions (Plutchik, 1994), or cognitive evaluations that occur together with a basic emotion (Oatley, 1992). Russell (2005) argued that emotional responses are derived from *core affect*, which he describes as “the neurophysiological state always accessible as simply feeling good or bad, energised or enervated, even if it is not always the focus of attention” (p. 26). This affective state arises from either conscious or unconscious evaluation or one's environment (Barrett, 2005). Primary emotions may reflect an unconscious, evolutionary adaptive appraisal, while evolutionarily recent secondary emotions may be the consequence of our ability to accurately categorise an instance of core affective feeling. The expression of this feeling may only be constrained by our vocabulary, rather than the expressive mechanisms such as facial expressions, which can betray basic emotions (Ekman, 1999b). The myriad of possible secondary emotions is reflected in (or limited by) the diversity and amount of words that Westerners can use to describe their emotional state; for example, *content*, *satisfied*, *perturbed*, *appalled*, *anxious*, and *depressed*.

2.1.3 *The Components of Emotion*

It is widely regarded that emotions comprise many components, including physiological concomitants (Plutchik, 1994), behavioural tendencies (Frijda, 1986), affective states (Lazarus, 1991), and cognition (Sloman & Croucher, 1981); and some emotions appear to be universally associated with, and recognisable by, characteristic facial expressions (Ekman, 1999b; Ekman & Friesen, 1986; Russell & Bullock, 1985). A small number of emotions with consistently identifiable neural correlates appear to serve biological functions related to the survival needs of the individual and of the species. Indeed, Damasio (2000) suggested that emotions originated as modulators of our interaction with the environment, to maximise our chances of survival; for example, the expeditious subcortical amygdalic response to conditioned fear is now well documented (de Gelder, Snyder, Greve, Gerard, & Hadjikhani, 2004; Garcia, Vouimba, Baudry, & Thompson, 1999; Grillon & Davis, 1997; Helmuth, 2003). However, as we have evolved as human beings, our neocortex has evolved with us (cf. Panksepp, 1994a). This evolution has brought with it a greater degree of differentiation of emotions or behavioural complexes (Bradley & Lang, 2000) than is possible with the limbic or reptilian subsystems of the triune[1] brain (Maclean, 1990). One result of this differentiation is the development of several distinct but broadly and necessarily overlapping approaches to the study of emotions, each of which is described below.

2.1.3.1 *The Neural Basis of Emotions*

The proliferation of sophisticated neuroimaging technology in the early 90s rendered the underlying neural mechanisms of affective states more accessible than ever before, and these phenomena became a tangible, not speculative, component of the debate (Scherer, 1993). Panksepp (1994a) argued that taxonomic discussions of emotions would never be resolved until emotion researchers begin to include brain circuit criteria in discussion of the underlying issues. But affective, behavioural, and cognitive neurosciences now provide powerful insights into the elicitation and expression of emotions (Panksepp, 1998, 2003), and emotion-processing structures in the brain have become increasingly more accurately mapped (Davidson, 2003, 2004; Davidson, Maxwell, & Shackman, 2004; Davidson, Pizzagalli, Nitschke, & Kalin, 2003; Patterson & Schmidt, 2003). Researchers have begun to identify both distinct neural systems (Adolphs et al., 2003) and physiological patterns (e.g., Rainville, Bechara, Naqvi, & Damasio, 2006) which relate closely to specific emotional states. Sensitivity to sensory feedback from viscera – interoceptive sensitivity – is implicated in emotion-processing structures in the brain (Critchley, Melmed, Featherstone, Mathias, & Dolan, 2002), and to verbal reports of experienced emotion (Feldman Barrett, Quigley, Bliss-Moreau, & Aronson, 2004).

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[1] Meaning: three-in-one. The human brain’s embryonic development moves from the differentiation of three somewhat primal subsections of the human brain – the forebrain, midbrain, and hindbrain – into the five major divisions we see in the adult brain: The telencephalon, diencephalon, mesencephalon, metencephalon, and myelencephalon. Maclean (1990) proposed that each new evolutionary layer has added species-characteristic repertoires of actions, which are intrinsically adaptive.

The main structures involved in the experience, expression, and regulation of emotion are housed within the *limbic lobe*, which is now more commonly referred to as the *limbic system*. This term describes structures on the inner margin of the neocortex, which came to be encased within the multi-layered outer cortices throughout reptilian and amphibian evolution, to form the three main divisions of the triune brain (Maclean, 1990). Maclean based his work on the musings of Papez (1937), who speculated that the hypothalamus, a diencephalic structure, was an integral structure in the expression of emotion; an assertion which has since been supported by the work of other emotion neurophysiology researchers (Berridge, 2003; Panksepp, 1998). One area of the brain which seems to constitute an evolutionary interface of emotion and cognition is the anterior cingulate cortex, which lies on the medial surface of each cerebral hemisphere and is structurally similar to neocortex, particularly motor areas (Allman, Hakeem, Erwin, Nimchinsky, & Hof, 2001). Thus, the neocortex and limbic system are intimately connected.

One particular structure in the limbic system, the amygdala, has received considerable attention in the neurophysiological study of emotion; primarily since damage to this structure was identified as a cause of Kluver-Bucy Syndrome, in which loss of normal fear and anger responses is a primary symptom (LeDoux, 1992). For this reason, examination of the amygdala has been largely confined to its role in the processing of fearful stimuli and in the expression of learned fear (Armony & Dolan, 2002; Garcia et al., 1999; Helmuth, 2003; Knight, Nguyen, & Bandettini, 2005; Ohman, 2005; Par, Quirk, & Ledoux, 2004; Tabbert, Stark, Kirsch, & Vaitl, 2005; Williams et al., 2005; Williams et al., 2004); although other fMRI evidence suggests that the amygdala may be involved in the emotional processing of the rewarding aspects of both monetary gains (Breiter, Aharon, Kahneman, Dale, & Shizgal, 2001) and music listening (Blood & Zatorre, 2001; Gosselin, Peretz, Johnsen, & Adolphs, 2007). This is certainly the case for the nucleus accumbens (Berridge, 2003), a small structure located between the striatum and basal forebrain, which is now well-established as a reward centre in the brain (Esch & Stefano, 2004; Mobbs, Greicius, Abdel-Azim, Menon, & Reiss, 2003).

Rolls (2005) viewed emotions as “states elicited by rewards and punishers, that is, by instrumental reinforcers” (p. 11), which represents a synthesis of his earlier ideas (e.g., Rolls, 1975, 1999a, 1999b). He argued that many theories of emotion which postulated appraisal as a key step in the development and/or expression of emotions (e.g., Frijda, 1986; Izard, 1993; Lazarus, 1991; Oatley & Jenkins, 1996; Oatley & Johnson-Laird, 1987; Scherer, 1999) must hold the assumption – implicitly or otherwise – that appraisal of something either rewarding or punishing is required. These views find some support from Schulkin, Thompson, and Rosen (2003), who identified appraisal as a key feature at many levels of neural organisation (cf. Izard, 1993).

Davidson (2003) acknowledged some longstanding misconceptions in the history of emotion research, which affective neuroscience has been able to redress to differing degrees: (a) Affect and cognition are subserved by separate and independent neural circuits; (b) affect is largely subcortical, while cognition is cortical; (c) emotions are in the head; (d) emotions can be studied from a solely psychological viewpoint; (e) similarity of emotion structure across age and species; (f) localisation of specific emotions within the brain; and (g) the intrinsic consciousness of emotional states. Each of these myths is now confronted by persuasive contradictory neuroscientific evidence (Adolphs et al., 2003; Berridge, 2003; Hagemann, Waldstein, & Thayer, 2003; Panksepp, 2003; Schulkin et al., 2003).

In defining an emotion, Damasio (1994) proffered a distinctly neural perspective:

> …emotion is the combination of a mental evaluative process, simple or complex, with *dispositional responses to that process*, mostly *toward the body proper*, resulting in

> an emotional body state, but also *toward the brain itself* (neurotransmitter nuclei in brain stem), resulting in additional mental changes. (p. 139)

Damasio (1994) described dispositional representations as “potential patterns of neural activity in small ensembles of neurons”; he calls these ensembles *convergence zones*, and they can develop through the learning process, wherein repeated firing of a set of neurons in response to a stimulus creates an increased likelihood that these neurons will fire again in response to either the actual triggering stimulus, or a mental representation/image of that stimulus. Therefore, imagery resulting from listening to music may be integral to the process by which emotions are generated.

Damasio’s (1994) definition does little to acknowledge the affective and experiential components of emotions. He later introduced a five-step course of events, which addresses this deficit. According to Damasio (2000), engagement of the organism via an inducer such as an emotive visual image occurs; this can happen unconsciously or consciously, and recognition of the inducer is therefore not a necessary step in the process. Once the image has been processed, neurons in convergence zones, which are preset to respond to the inducer, fire. Bodily and further neural changes – as he alluded to in his earlier definition – then ensue. Fourth, changes in body state are represented subcortically and cortically in first-order neural maps; this is what we might describe as a *feeling* – which need not be recognised as such. Finally, second-order neural sites are activated, which enable us to have a *feeling of a feeling*. It is this cognition of our bodily states that Izard (1994b) proposed leads to differentiation of what he terms *emotion experience*. This, according to Izard, is a *quality* of consciousness, primarily feeling or affective tone. He noted some descriptors that capture its essence: Motivating condition, feeling state, change or shift (*bias*) in perception, cues for cognition, action readiness, or action tendency (Frijda, 1986).

2.1.3.2 *Emotion and Motivation*

2.1.3.2.1 *Action tendencies*. Frijda (1986) noted that appraisal does not lead directly to action. Instead, he suggested that appraisal is followed by an *impulse*; in other words, the instigation of an *action tendency*, which is a state of readiness "to achieve or maintain a given kind of relationship with the environment. [Action tendencies] can be conceived of as plans or programs to achieve such ends, which are put in a state of readiness" (p. 75). An impulse is best understood as a goal which can be achieved by different plans (Frijda, 1995). For example, the goal to remove an obstacle for concern satisfaction (as in the case of anger) can be achieved by different forms of aggressive behaviour, such as a bodily attack or a verbal threat; Frijda (1986) called the action tendency underlying aggressive behaviour "agonistic". Further, an impulse has the feature of control precedence: It tends to interrupt ongoing processes and to take control over behaviour, attention, and resources.

Regardless of type, action tendencies eventually lead to action. Frijda (1986) distinguished between instrumental activity and expressive behaviour. In contrast to expressive behaviour such as facial expressions, instrumental activity directly changes the world's objective state by overt action (e.g., by attacking a rival) or by cognitive action (e.g., by deprecating a rival's worth in one's mind). Thus, a feeling of surprise in response to an unexpected stimulus may create an impulse to remove oneself from the source of surprise, which could arguably be described as an *avoidance action tendency*. Indeed, Cerin (2003) found that emotions with clear approach or avoidance action tendencies were reasonably consistent predictors of emotion functionality, in regard to their ability to facilitate performance across a range of individual sports.

But Frijda's (1986) view does not take into account our ability to constrain our expression of emotion. While acknowledging that emotions can activate predetermined behavioural tendencies, which may ordinarily reside at the very lower echelons of behavioural hierarchies, Levenson (1994) espoused the notion that different degrees of cultural learning enable us to modify our expression of recruited response tendencies; for example, via *display rules* (Ekman, Sorenson, & Friesen, 1969). Display rules govern how emotions should be expressed within a particular culture; facial expressions are a behavioural component of emotions whose pan-cultural commonalities and differences have been extensively investigated by Paul Ekman and his colleagues (Ekman, 1972, 1999b, 2004; Ekman & Friesen, 1986; Ekman et al., 1969).

2.1.3.2.2 *The role of intensity and valence in approach and avoidance*. Perhaps the most striking evidence for the structural integrity of the circumplex model (see Section 2.1.3.5.3) is the existence of psychophysiological indices of affective states. Heller (1990) proposed the existence of two separable neural systems for the modulation of emotional valence (located in the frontal lobes) and arousal (located in the right parietotemporal region). Heller hypothesised that emotional state was determined by the relative activations of these two systems, and put forward the model in Figure 2.2. Using this model as a guide, the subjective experience of happiness, which entails both high valence and high arousal, would necessitate greater left frontal lobe activation in combination with higher right parietotemporal activation. Heller (1993) subsequently conceded that individual differences should be taken into account when assessing cerebral activity patterns. Nonetheless, strong evidence corroborates the existence of these dimensions, independently of personality, from both electroencephalographic (Schmidt & Trainor, 2001) and neuroendocrinological (Henry, 1986) data.

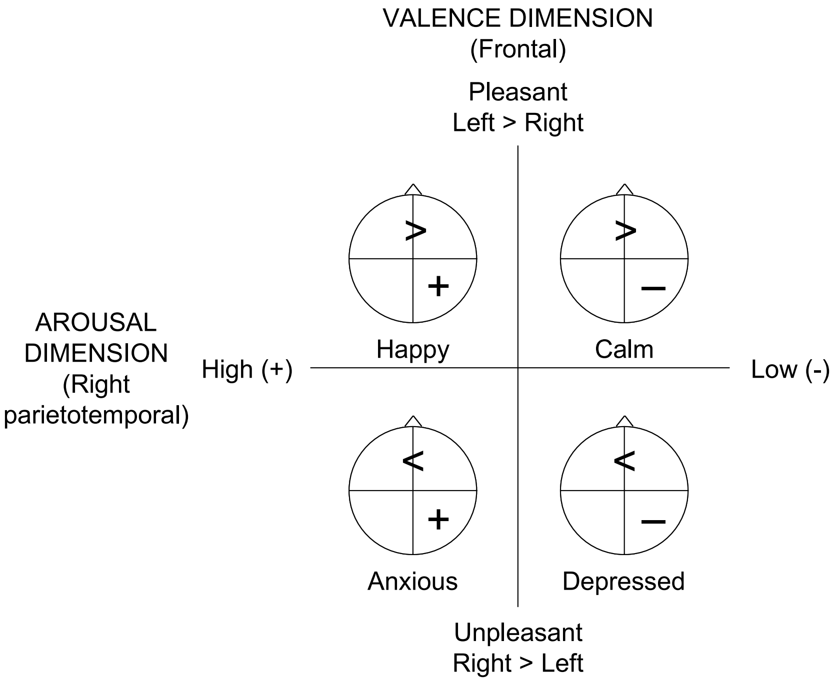

Figure 2.2. Hypothesised patterns of right parietotemporal and left frontal region activity during the experience of different emotions, differentiated according to the circumplex model (adapted from Heller, 1993).

In their examination of asymmetrical hemispheric activation on approach and withdrawal responses, Schiff and Bassel (1996) conceptualised finger flexion and extension as approach and withdrawal responses, respectively, due to their associations with grasping and releasing objects. Participants were asked to extend or flex the index finger of their right hand in response to an auditory stimulus, in a between-subjects design comprising three facial contraction conditions: Left side, right side, and a no-contraction control. The difference between baseline and post-contraction reaction times was the dependent measure. Results of the first of two experiments showed that right-sided contractions (activating the left hemisphere) facilitated approach responses with the right hand; experiment 2 results indicated that left-sided contractions facilitated withdrawal responses of the left hand. However, neither of the experimental procedures elicited notable affective responses, as measured on a 21-point mood scale. The authors rightly concluded that their results may simply reflect the lateralisation of sensory and motor systems.

Schmidt and Trainor's (2001) investigation of emotional responses to music lent support to Heller's model. They used EEG to examine 59 undergraduates' cortical responses to musical excerpts pre-selected for their collective representation of different affective valences (i.e., positive and negative) and intensities (i.e., intense and calm). Overall frontal activity was more pronounced in the more intense emotions of *fear* and *joy*, when contrasted with *happy* and *sad*; these former emotions also have clearer action approach or avoidance action tendencies (Frijda, 1987) associated with them. There was significantly greater activation in left frontal lobe in response to positively valenced music; the converse was true for negatively valenced music. Negative intense emotions also evoked greater frontal activity overall. However, parietal activations did not differ significantly. Schmidt and Trainor concluded that the pattern of frontal lobe activity can differentiate emotional responses to music, based on the dimensions of valence and intensity. Because the frontal lobes are the location of the motor cortex, this finding may present implications for the functionality of the intensity of experienced emotions in motor behaviour.

2.1.3.3 *Facial Expressions*

Darwin (1872/1999) first commented on the "remarkable uniformity" of facial expressions across cultures, when he collated information from Englishmen living in Africa, America, Australia, Borneo, China, India, Malaysia, and New Zealand. However, there were some flaws to his method, as noted by Ekman (1999b): As well as using a small sample, he relied upon the Englishmen's answers, rather than answers from individuals within the cultures of interest; his questions were somewhat leading, in that they would combine the emotion of interest with the expressive characteristics of interest in the same question (e.g., "Is astonishment expressed by the eyes and mouth being open wide, and by the eyebrows being raised?”); and he did not use photographs to ascertain the emotions that people saw in other cultures, as he did in England.

Considerable evidence exists for the innateness and universality of facial expressions of some discrete emotions across both cultures and developmental stages of the human life cycle (Ekman et al., 1969; Izard, 1994a; Russell & Bullock, 1985). Ekman et al. (1969) used photographs developed by Tomkins (1962) to investigate the recognition of emotions in literate and preliterate cultures, and concluded that, although there was generally greater agreement between literate cultures, a strong association between facial muscular movements and discrete primary emotions exists globally. Ekman (1992b) later suggested that basic emotions should be characterized not only by their comparative brevity (2-3 min), but also that they should be accompanied by a specific cross-culturally stable facial expression pattern.

Although there are cross-cultural universals amongst facial expressions (Ekman et al., 1969), different cultures may mask their expression of emotions differently: Ekman (1972) asked American and Japanese participants to view films of surgery and accidents, and they displayed the same facial expressions in response to the films. But when a researcher was present to observe the same participants, the Japanese participants tended to mask their negative emotions with a smile more than did their American counterparts. Thus, in the measurement of facial expression as an indicator of emotion experiences in sport, one must be sensitive to potential cultural differences.

In addition, evidence has since accumulated to suggest that the concomitant neurophysiological response to such facial expressions of emotions manifests itself in identifiable patterning across cultures (Levenson, Ekman, Heider, & Friesen, 1992) and different age groups (Levenson, Carstensen, Friesen, & Ekman, 1991). However, the notion that voluntary (i.e., non-emotion-elicited) facial action can generate emotion-specific autonomic activity (Levenson et al., 1990) somewhat belies Ekman's (2004) notion that false facial expressions of emotion are betrayed by *micro expressions*, minute flickers of facial activity lasting less than one-fifth of a second; one might reasonably expect that, with practice, anyone so choosing could override these micro expressions to elicit an entirely convincing emotional response, much as an accomplished actor would.

2.1.3.4 *Physiological Markers of Emotion*

William James (1890) promoted the notion that emotions are accompanied by unique patterns of somatic and autonomic activity, but this was later superseded by Schachter and Singer's (1962) proposition that cognitions, not physiological states, differentiate emotions. Since then, the question of whether emotion-specific physiology exists has been all-but-answered. While emotion physiology researchers are largely unanimous in their agreement that (a) the primary emotion of disgust is associated with lower heart rates than other primary emotions and (b) that anger is associated with greater skin temperature than fear (Davidson & Ekman, 1994b), there is also some consensus that the search for emotion-specific physiology should examine the central nervous system (Hagemann et al., 2003; LeDoux, 1994; Panksepp, 1994b). However, Schulkin et al. (2003) suggested an important role for the appraisal of peripheral and visceral signs of emotion, an idea that complements Damasio's (1994) somatic marker hypothesis.

Brosschot and Thayer (2003) tested the hypothesis that heart rate responses associated with negative emotions would be prolonged compared to responses associated with positive emotions. Over an 8 hr period, 33 healthy participants were required to report their emotional arousal, emotional valence, and physical activity, and to record their heart rates (HR) every hour (*initial HR*, T0), followed by two prolonged *activation recordings*, respectively 5 min later (T1) and 10 min later (T2). While emotional arousal and activity predicted initial HR, prolonged activation at T1 was solely predicted by negative affect at T0, independent of emotional recovery, lending support to Brosschot and Thayer's (2003) hypothesis that cardiovascular activation after negative emotions lasts longer than after positive emotions. They concluded that prolonged activation, and not so much initial reactivity, may be a mechanism underlying the causal role of negative emotions (e.g., stress) in somatic disease.

Rainville et al. (2006) investigated ECG and respiratory activity during the experience of fear, anger, sadness and happiness. Data were recorded in 43 healthy volunteers during the recall and experiential reliving of one or two potent emotional autobiographical episodes and a neutral episode. Rainville et al. observed significant increases in heart rate for all four emotions relative to the neutral condition, which they suggested was a reflection of combined sympathetic and parasympathetic activity. Pairwise comparisons revealed differentiation of responding in the different emotion conditions. Nyklícek et al. (1997) investigated the capacity of cardiorespiratory variables to distinguish discrete emotions which had been semantically defined beforehand. Twenty-six participants aged 18 to 26 yrs listened to 12 music excerpts depicting four emotions (happy, serene, sad, and agitated; three excerpts for each), as well as to a white noise condition. The emotion categories were successfully classified using discriminant analysis according to a respiratory component, which was related to the arousal dimension of self-reported emotions, and heart rate. Their results supported the notion that discrimination of lower-order discrete emotions can be located somewhere along a limited number of higher-order dimensions, such as arousal and valence.

2.1.3.5 *Mood, Cognition, and Affective States*

2.1.3.5.1 *Emotion-mood distinctions.* The drive to distinguish between emotion and mood has been an area of interest for some time (Batson, Shaw, & Oleson, 1992; Beedie et al., 2005; Terry, 2004), although researchers typically agree that a distinction does exist (Davidson & Ekman, 1994a). Emotions and moods can be distinguished from one another in a number of ways, but Davidson (1994) has suggested that the primary function of emotions is to bias action; Levenson (1994) argued that emotions choreograph various combinations of central, somatic and autonomic activity to facilitate that action. Davidson (1994) suggested that the function of moods, on the other hand, is to modify our cognitions, but does not elaborate on the adaptiveness of these modifications. Nonetheless, Isen (1987) suggested that positive moods can promote flexibility in cognitive processes, engendering greater creativity and enhanced decision-making. Also, positive emotional states can lead to enhanced perceptual functioning (Ashby, Isen, & Turken, 1999). Isen's (1987) assertion has since found support from Morris (1992), who suggested that the function of moods is primarily to signal self-states, in order to mobilise physical, psychological, and social resources available to meet perceived environmental demands.

Morris's (1992) contention somewhat mirrors Damasio's (1994) concept of *background feelings*, which he describes as the bodily state that prevails *between* emotions. These states provide a reference point, to which all subjective assessment of our affective state can be firmly anchored. For example, we may not be overcome with a strong emotion at any given point in time, nor do we need to be aware of our affective state when performing an activity. But if we were asked to describe our state of being, we would be able to do so; this is our background feeling. Damasio appears to deliberately shun the use of the word "mood" in his discussion of human emotions. He argues that the distinction between background feelings and moods is one of temporality: "When background feelings are persistently of the same type over hours and days, and do not change quietly as thought contents ebb and flow, the collection of background feelings probably contributes to a mood, good, bad, or indifferent" (p. 151). Damasio lists descriptors such as *tension*, *fatigue*, and *energy*, all of which are concepts that have been considered mood constructs (e.g., the Profile of Mood States; McNair, Lorr, & Droppleman, 1971); thus, the distinction is slight.

The notion of temporality in distinguishing moods from emotions appears to be a reliable one. Beedie et al. (2005) performed content analyses (see Weber, 1985) of (a) questionnaire data from 106 participants who had responded to the opening question “What do you believe is the difference between an emotion and a mood?” and (b) 65 contributions to the academic body of emotion literature. Almost 40% of questionnaire respondents suggested that moods are of a longer duration than emotions, and 62% of academic authors indicated the same. Beedie et al.’s (2005) data also indicated that a recognisable antecedent event may distinguish emotion from mood; the latter having no attributable cause. Davidson (1994) had earlier contested this notion, citing Kunst-Wilson and Zajonc’s (1980) investigation of the effects of subliminal (preconsciously processed) stimuli as evidence that antecedents need not be perceptible. Triggers for moods may also be more subtle, such as the weather (Schwarz & Clore, 1983). The cause-effect relationship of emotions and perceptible triggers may be reflected in the fact that there is a measurable autonomic response in emotions (Hagemann et al., 2003); the type of activity serves to differentiate between the emotions to some degree (Ekman et al., 1983). Autonomic response is one of a number of measurable emotion components (see Bradley & Lang, 2000), whereas moods are often gauged by an individual’s subjective experience (i.e., self-report; cf. Panksepp, 1994a).

2.1.3.5.2 *Measuring affective states*. Self-report measures have been the mainstay of the assessment of emotional experience (e.g., Almagor & Ben-Porath, 1989; Feldman Barrett et al., 2004; Kerr & Svebak, 1994); they typically require that the respondent rates, on a Likert-type scale, the degree to which an emotion adjective represents their current or recent emotional state. Pivotal to *categorical approaches* when measuring affective states is the previously discussed class of primary/basic emotions, which collectively form the basis for all other emotional states. For example, one of the earliest measures of mood, Nowlis’ (1965) Mood Adjective Check List, consists of 38 mood-related adjectives which subdivide into 11 factors including *anxiety*, *depression*, *happiness*, and *aggression*; these resemble, to varying degrees of departure, the primary emotions of fear, sadness, happiness, and anger respectively.

The Differential Emotions Scale (Izard et al., 1974) is another self-report measure that assumes an integral role for 10 prototypical emotions in measuring emotional experience; these are *interest*, *joy*, *surprise*, *distress*, *anger*, *disgust*, *contempt*, *fear*, *shyness*, and *guilt*. Differential Emotions Theory (Izard, 1977), which was borne out of this earlier research, views emotional experience as a feeling state or motivational condition; and it is straightforward to see the relationship between each of the aforementioned emotion prototypes and motivation to action.

A criticism that could be levelled at categorical approaches to the study of emotion is the implicit acceptance that an individual's emotional experience is reducible to pre-specified categories of emotions, which ultimately precludes any description of emotions not described in the measure. *Dimensional approaches* to emotion measurement allow for idiosyncrasies in the subjectivity of affective experience, in that they seek to identify emotions based on a comparatively small number of dimensions, such as *valence*, *activity*, and *dominance* (Mehrabian & Russell, 1974). Dimensions such as these often underlie seemingly categorical measures of emotion and mood; for example, Zuckerman and Lubin (1985) constructed the 132-adjective Multiple Affect Adjective Checklist-Revised, which differentiates into five independent dimensions: *anxiety*, *depression*, *hostility*, *positive affect*, and *sensation seeking*.

An arousal/activation dimension is implicit in many proponents' view of emotion (e.g., Mehrabian & Russell, 1974; Plutchik, 1994; R. E. Thayer, 1989). R.E. Thayer (1967) was one of the earliest proponents of arousal as a fundamental feature of affective experience, and developed the Activation-Deactivation Adjective Check List (AD ACL) to assess the instantaneous presence or absence of different arousal states. The items can be divided into four subscales, *Energy*, *Tiredness*, *Tension*, and *Calmness*, which purportedly represent two independent dimensions of *energetic arousal* and *tension arousal*. The AD ACL appears to work best when assessing psychophysiological states (Mackay, 1980), and the underlying dimensional structure is consistent with other theories of mood and arousal (Purcell, 1982; Watson & Tellegen, 1985).

Watson and Tellegen (1985) argued that two dimensions consistently predict the diverse categories of affective states experienced by individuals: *Positive affect* (PA) and *negative affect* (NA); although they were quick to note that one should not infer that all affective experience is reducible to these two dimensions, but that they form the basis for the discrete emotions posited by other emotion theorists (Izard, 1972; Nowlis, 1965). Watson, Clark and Tellegen (1988) later developed the Positive and Negative Affect Schedule (PANAS), a 20-item self-report measure of positive and negative affect. Despite Watson and Tellegen's (1985) promotion of the independence of positive and negative affect, Watson and Clark (1992) later investigated the structure of four chiefly negative affective states (fear, sadness, hostility and guilt), and found one strong underlying dimension: Negative affect. Watson and Clark (1992) concluded that, within each of the two dimensions, affective states were closely related. However, Kennedy-Moore, Greenberg, Newman and Stone (1992) showed that scores on the PANAS did not correspond with scores on the Mood Adjective Checklist (Nowlis, 1965) over the course of a week.

Watson and Clark (1997) discussed the continued independence of the positive and negative affective dimensions throughout their empirical studies, although they later conceded that PA and NA ought to be defined by the degree of activation of positively and negatively valenced affects (cf. Watson, Wiese, Vaidya, & Tellegen, 1999). Diener and Iran-Nejad (1986) asked participants to read stories designed to generate PA or NA. They found that PA and NA could not coexist at high levels of intensity. However, subsequent research by Larsen, McGraw and Cacioppo (2001) suggested that a bivariate, not bipolar, structure should be adopted when assessing happiness and sadness concurrently; a finding which contradicts that of Russell and Carroll (1999), but finds support in Tellegen, Watson, and Clark's (1999) study, which revealed no correlations between PA and NA.

2.1.3.5.3 *The circumplex model of affect*. Russell's (1980) circumplex model of affect (a variant is shown in Figure 2.3) comprises two bipolar perpendicular dimensions – perceived activation (*arousal*) and affective valence (*pleasure-displeasure*) – which bisect to subdivide the circumplex model, yielding four quadrants; proponents of this model contend that all experienced emotions can be located at some point within one of the four quadrants. For example, excitement lies in the extremities of the quadrant bordered by the upper halves of the activation and valence continua (highly arousing – highly pleasant). This model stems from the concept of *basic affect*, which can be described as "the subjective experience that accompanies all valenced (positive or negative) responses to distinct emotions as the stimulus-linked affective states that are elicited following specific patterns of cognitive appraisals" (Ekkekakis & Petruzzello, 2002, p. 36). Also, emotions lying across the model from one another tend to be negatively correlated, suggesting a bipolar, not bivariate, structure to the model. Suggestions of a third dimension (e.g., Mehrabian & Russell, 1974) have been largely dismissed (e.g., Russell, 1997), due to the large variance in the model accounted for by the valence and arousal dimensions. The circumplex model has also stood up to cross-cultural testing (Russell, 1983; Russell, Lewicka, & Niit, 1989), and is considered a suitable measure of the affective experiences of psychiatric patient groups (Kring, Feldman Barrett, & Gard, 2003) and exercisers (Ekkekakis & Petruzzello, 2002).

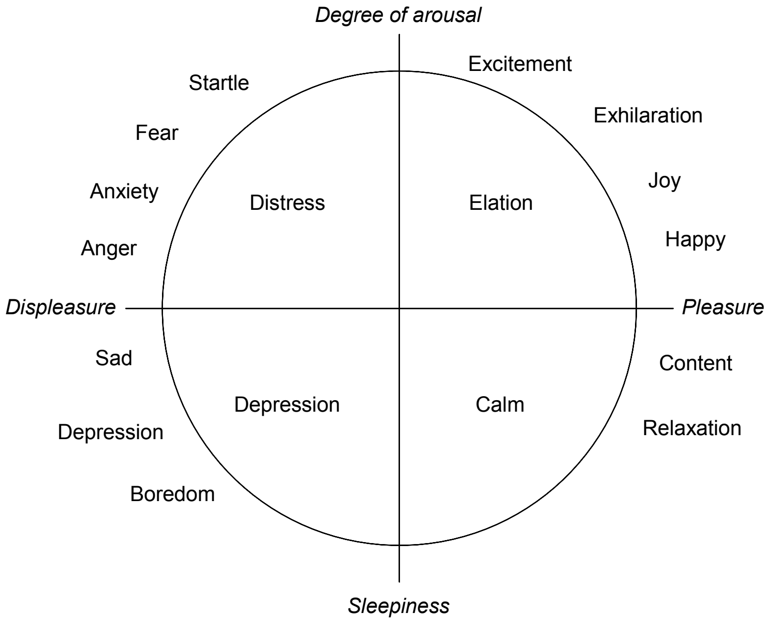

Figure 2.3. A circumplex model for emotions (adapted from Russell, 1997).

Russell (2005) promoted the concept of valence as a fundamental feature of all affective phenomena, an approach supported by Panksepp (2000), who proposed the notion that valenced affective feeling states provide fundamental values for the guidance of behaviour. But due to its broad-brush nature, the circumplex model leaves itself open to criticism, the most prominent of which is the model's failure to differentiate between various emotions and their interrelationships (R. J. Larsen & Diener, 1992). For example, the primary emotions of anger and fear are highly correlated within the model, yet their implications for the organism are considerably different (Sloboda & Juslin, 2001). Mayer, Salovey, Gomberg-Kaufman and Blainey (1991) showed that two dimensions, pleasant-unpleasant and arousal-calm, could characterize physical, emotional, and cognitive subdomains of emotion, although Mayer et al. (1991) argued that the broader mood dimensions of *Action*, *Suppression*, and *Denial* were more predictive of subsequent action-oriented manifestations of emotion-related experience.

Russell, Weiss, and Mendelsohn (1989) developed the Affect Grid, a single-item measure which they concluded to be a reliable and valid measure of both arousal and valence.

Respondents are required to mark a cross in one box on a nine-by-nine grid, to denote their emotional state in relation to the two dimensions. The vertical dimension represents arousal, and the horizontal dimension represents pleasure. This single-item measure has since been successfully employed as a measure of in-task affect during simulated driving performance (Edmonds, Mann, Tenenbaum, & Janelle, 2006).

The circumplex model represents an efficient means for assessing the subjective affective experience arising from musically-induced emotions, despite the fact that it sometimes does not provide clear distinctions between seemingly diverse emotion descriptors. The evolutionary utility of the underlying two-dimensional structure of the circumplex model is captured by J. F. Thayer and Faith (2001), who remarked that valence represents the evaluative outcome necessary to initiate an approach or withdrawal response (cf. J. A. Gray, 1994), and arousal reflects the resource investment in the action tendency (cf. Frijda, 1987). For researchers wishing to make fine discriminations between emotion states, categorical measures may provide a useful complement to circumplex-based ones.

2.2 Emotion, Mood, and Sports Performance

Mood and emotions have been an area of considerable focus in sport (Terry, 2004). Emotions exert diverse effects on performance (Lazarus, 2000), and athletes' emotional states fluctuate throughout the duration of athletic competition (Jones & Mace, 2000). Despite a wide array of self-reported emotions constrained only by our vocabulary, self-confidence and anxiety have remained the predominant affective phenomena of investigation in sport (e.g., Bray & Martin, 2003; Butt, Weinberg, & Horn, 2003; Craft, Magyar, Becker, & Feltz, 2003; Feltz, 1988; Hanton, Mellalieu, & Hall, 2004; Hanton, Mellalieu, & Young, 2002; Mellalieu, Hanton, & Jones, 2003); this is the case in spite of the lack of a conceptually clear definition of either self-confidence or anxiety as an outright emotion. Differential Emotions Theory (DET; Izard, 1977), for example, posits that anxiety is a *complex* emotion potentially encompassing both approach and avoidance action tendencies, and Lazarus (1999) asserted that self-confidence is a positive non-emotional state.

Craft et al. (2003) found only weak relationships between cognitive anxiety, somatic anxiety, self-confidence and performance in a meta-analysis of a number of studies involving the Competitive State Anxiety Inventory-2 (CSAI-2; R. Martens, Burton, Vealey, Bump, & Smith, 1990); self-confidence showed the strongest relationships. Cerin (2003) asked 202 athletes to recall pre-competitive emotions before their best ever and worst ever competitions. She concluded that emotions characterized by a clear action tendency would be better predictors of athletes' perceived functionality of emotional states than anxiety scales based on a unitary conceptualisation of anxiety, in line with Izard's (1977) DET. Nonetheless, traditional measures of emotion in sport and exercise have principally examined diverse arrays of affective experience which comprise secondary emotions – which may not necessarily be functional in sporting contexts (Cerin, 2003).

2.2.1 *Traditional Nomothetic Approaches to Measurement of Emotion*

Measurement of emotion and mood has been an area of ongoing concern in sport, largely in relation to the development of valid and reliable psychometric tools (Lane, 2004). Traditional nomothetic approaches to assessment of precompetitive emotion or mood (e.g., Sport Emotion Questionnaire, [SEQ] Jones, Lane, Bray, Uphill, & Catlin, 2005; Profile of Mood States, [POMS] McNair et al., 1971) typically require the respondent to indicate the extent to which they feel each emotion in a predetermined array, reflecting a categorical approach to emotion measurement. The POMS (McNair et al., 1971) has been a major tool in the investigation of sport-related emotion (e.g., Terry & Lane, 1998). The *Iceberg Profile* (Morgan, 1980) has distinguished high-performing Italian national rifle shooters in World Cup competition (Cei, Manili, Taddei, & Buonamano, 1994) and successful collegiate tennis players (Covassin & Pero, 2004) from less successful athletes; and Rowley and Landers'

(1995) meta-analysis revealed an overall positive profile across 33 different studies that employed the POMS.

Stevens and Lane (2001) investigated mood-regulation among 107 athletes and found that athletes reported listening to music as a strategy for regulating each of the six dimensions of the POMS: *Tension*, *depression*, *anger*, *vigour*, *fatigue* and *confusion*. Further, music listening was the predominant strategy for regulation of anger (44.86% of the sample) and tension (41.12%). One criticism of the POMS is that it is oriented towards negative mood states/emotions (Lane & Terry, 2000), a contention partly supported by Cerin (2003), who found that the positive emotions of excitement and enjoyment, as well as the negative emotions of sadness, guilt, and self-hostility, appeared to be more significant emotional states than anxiety or fear.

While the investigation of anxiety and the subscales of the POMS have been popular in the investigation of emotion in sport, exercise psychologists have developed measures which embrace more components of the affective response (Gauvin & Rejeski, 1993; McAuley & Courneya, 1994). Perhaps the most notable departure from the norm is the Exercise-induced Feeling Inventory (EFI; Gauvin & Rejeski, 1993). This 12-item measure subdivides into four subscales, namely *positive engagement*, *revitalization*, *tranquillity*, and *physical exhaustion*. Ekkekakis and Petruzzello (2001) critiqued the EFI, largely for its a priori framework, which the authors generated in order to take a discrete approach to affect measurement; they did this in spite of the fact that that Gauvin and Brawley (1993) had contemporaneously written a chapter in which they extolled the virtues of a dimensional approach to studying affect in the exercise context. Also, Gauvin and Rejeski (1993) did not present a convincing rationale for the development and subsequent inclusion of the four subscales; a notable omission.

A concurrent development yielded the Subjective Exercise Experiences Scale (SEES; McAuley & Courneya, 1994), another 12-item scale, but with only three subscales: *Positive Well-Being*, *Psychological Distress*, and *Fatigue*; this more parsimonious structure may reflect the fact that McAuley and Courneya (1994) conceptualised the SEES as a dimensional measure, in contrast to the EFI's categorical approach. The authors also criticised other measures, such as the POMS (McNair et al., 1971) and PANAS (Watson et al., 1988), for their lack of consideration of environmental elicitors of emotions. However, the measurement of emotion only in exercise-specific environments will invariably limit generalisability. This has been borne out in subsequent research: Rudolph and Kim (1996) used the SEES to assess mood responses in a sample of 108 Korean physical education students. In contrast to findings from exercise research – which has shown decreases in negative affect as a result of engaging in exercise (e.g., Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991) – participation in four different sporting activities (aerobic dance, soccer, tennis, and bowling) did not lead to reductions in psychological distress.

Lox, Jackson, Tuholski, Wasley, and Treasure (2000) noted the core similarities in the EFI and SEES, and identified the existence of a high degree of correlation between the Positive Well-Being subscale of the SEES and the Revitalization and Positive Engagement subscales of the EFI, and between the Fatigue subscale of the SEES and Physical Exhaustion subscale of the EFI. Lox et al. combined the two to form the Physical Activity Affect Scale (PAAS), a 12-item measure tapping into four components of exercise-induced affect: *positive affect*, *negative affect*, *fatigue*, and *tranquillity*. The authors asserted that the PAAS provides a comprehensive measure of exercise-induced feeling states. But even a simple visual inspection of the measure suggests that only one item, *energetic*, taps into an affective state that is both positive and arousing; a state which is often a consequence of physical activity (R. E. Thayer, 1989).

The measurement of emotion in sport has been largely confined to the resultant or preceding affective experience. Tenenbaum and Elran (2003) examined differences in actual and retrospective reports of emotions for pre- and post-competition states; these varied, reflecting findings in mainstream emotions research (Winkielman, Knauper, & Schwarz, 1998). Sève, Ria, Poizat, Saury, and Durand (2007) tried to address this issue head-on by examining experienced emotions during high-stakes table tennis matches. Perhaps unsurprisingly, emotional ratings were closely related to scores in sets and identifiable moments within sets.

Cerin, Szabo, Hunt, and Williams (2000) conducted a review of studies which had examined pre-competitive affective states, and found a preponderance of anxiety-based measures. They also noted that popularised nomothetic measures tended to neglect both temporal aspects of affectivity and other contextual factors such as the phase of an athlete's career. Cerin et al. suggested that the athlete's situational appraisal is key in determining their emotional response (cf. Scherer, 1999), and that future research should therefore investigate the similarities and differences in the patterning of pre-competitive secondary emotions across competition phases and individuals, by combining nomothetic and idiographic methods.

2.2.2 *Idiographic Approaches to Measurement of Emotion*

Hanin (1995; 1997; 2000a) propagated the idiographic approach to the investigation of facilitative and debilitative emotions in sport – the Individual Zones of Optimal Functioning (IZOF) model – in which the athlete identifies a unique range of experienced precompetitive emotions according to both their content (in broad terms, positive vs. negative) and their functionality. Functional emotions are those deemed by the athlete to be facilitative to performance, whereas dysfunctional emotions hinder performance. Five fundamental components conjointly delineate individually functional and dysfunctional performance-related emotion experiences: Form, content, intensity, time, and context. Subsequent research has supported the notion that idiosyncratic emotional profiles based on these dimensions can differentiate successful and average athletic performance (Robazza, Bortoli, & Hanin, 2004; Robazza, Pellizzari, & Hanin, 2004); and the IZOF model may be applied in dealing with competition anxiety (Annesi, 1998).

Robazza et al. (2004) developed idiosyncratic emotional profiles for each of 10 karateka; these were based on the athletes' recollections of their best and worst performances. A novel addition to their study design was to include the athletes' appraisals of their bodily symptoms drawn from a list of 45 descriptors of both pleasant and unpleasant bodily experiences (e.g., "relaxed muscles" was considered a facilitating-positive bodily state). These descriptors contributed to the athletes' overall emotional profiles, along with more traditional affective descriptors, and task-specific descriptors of what must be effected in competition in order to succeed. Intraindividual analyses showed that bodily symptom scores were capable of differentiating good and bad performances, which not only lends further support to the IZOF model, but also suggests that there may be physiology specific to idiosyncratic emotional states; the presence of such emotion-specific physiology for basic emotions is debatable (Davidson & Ekman, 1994b; LeDoux, 1994; Levenson et al., 1990; Nyklícek et al., 1997).

Cohen, Tenenbaum, and English (2006) modified Kamata, Tenenbaum, and Hanin's (2002) probabilistic model of the individualised zone of optimal functioning in their examination of the efficacy of a psychological skills intervention. Two golfers (both Major Division I players in the southeastern US) provided scores on the Affect Grid (1989), the Test of Performance Strategies (TOPS; Thomas, Murphy, & Hardy, 1999), and for positive and negative affect (PNA; Hanin, 2000b). The functionality of emotions experienced and perceived ratings of their performance were rated using nine-point scales (analogous to those of the Affect Grid) immediately after playing each hole, together with Affect Grid scores. The PNA measure was completed after each round of competition, and the TOPS was completed after the second and fourth of four tournaments. Individual emotion-related performance zones were developed for each player, for all three emotion measures – arousal, pleasantness, and functionality. Cohen et al. concluded that more research was needed to support Kamata et al.'s model. Perhaps more importantly, they identified that (a) performers may not always be able to successfully report an optimal performance zone, and (b) good performance can occur in the presence of dysfunctional emotions. Another point of note is that neither of the participants wished to contribute IZOF during the latter half of the season, as they considered the data collection procedures too invasive. Therefore, it may be prudent in future, to correlate scores taken from the Affect Grid (a relatively expeditious measure) with individually-derived IZOF data for use in competitive situations.

2.2.3 *The Circumplex Model in Sport and Exercise*

Ekkekakis and Petruzzello (2000) examined (a) the distinctions between emotions, moods, and affect; (b) the strengths and weaknesses of categorical and dimensional models for conceptualizing affective phenomena; (c) the notion of exercise-specific affect; and (d) whether measurement should be based on a deductive or an inductive approach. They presented arguments in favour of (a) targeting basic affect as the appropriate object of assessment at the present stage of knowledge development; (b) adopting dimensional models because of their broad and balanced scope; (c) critically reconsidering the notion of exercise-specific affect; and (d) using deductive methods for measuring affect.

Ekkekakis and Petruzzello (2002) later put forward the conceptual case for the circumplex model in measuring exercise-related affect, in order to address deficits the authors had seen in other, categorical measures. From their review of studies measuring exercise-related affect and studies investigating the circumplex model, Ekkekakis and Petruzzello concluded that (a) basic affect should be the primary affective phenomenon of interest in exercise emotion research; (b) dimensional models are more appropriate than categorical measures, due to their scope, balance, and parsimony; and (c) subsequent measures of emotion in exercise should be global, not domain-specific, to enable cross-contextual generalisation. Judged solely on these criteria, the circumplex model appears a useful and potentially valid measure of exercise-related affect, at least.

A circumplex structure may exist in other well-established measures of affect: Ekkekakis, Hall, and Petruzzello (2005) found that a short version of the AD ACL (R. E. Thayer, 1989) displayed a good fit to the circumplex structure, when assessing participants emotional responses to a short walk. One hundred and sixty-five participants completed the AD ACL before and after a short walk. Before the walk, the circumplex model provided a close fit to the data, whereas, after the walk, the fit was lower, but still reasonable. Ekkekakis et al. (2005) noted that at neither point in time did items theorised to belong to one subscale become interspersed with items theorised to belong to an adjacent subscale. These findings may not, however, be replicated with more categorical measures; R. E. Thayer (1989) noted that the AD ACL has an underlying dimensional structure.

Sporting applications of the circumplex model are severely limited. Hardy, Hall, and Alexander (2001) asked 90 high school athletes to complete the Affect Grid (Russell, Weiss et al., 1989) and a Self-Talk Grid before practice and competition. Hardy et al. (2001) identified a moderate relationship between self-talk and affective state. Edmonds et al. (2006) asked three male participants to provide self-report data for affective states using the Affect Grid (Russell, Weiss et al., 1989) during performance of a video car racing game; physiological data were obtained concurrently. The affective data obtained were sufficient to tentatively identify individualised optimal performance zones for each of the participants. Given the parsimonious structure of the circumplex model, and the ease of completion of a single-item measure such as the Affect Grid (Russell, Weiss et al., 1989), further consideration should be given to their use in a sporting domain.

2.2.4 *Imagery*

Images form a crucial part of Damasio's (1994) concept of dispositional neural patterns, or representations, which he suggests hold the means to reconstruct a "picture" of an emotion inducer, although this may be represented in all sensory modalities, not just the visual modality. Damasio (1994) used the example of a dispositional representation of "Aunt Maggie". In remembering what Aunt Maggie looks like, the physical stimulus (i.e., Aunt Maggie) need not be present, but several visual, auditory, somatosensory, and higher-order association cortices may fire to produce an image of what her face looks like, what her voice sounds like, and what the skin of her hand feels like to touch. Her image does not reside within one site in the brain, but is distributed all over it, in the guise of multitudinous representations, each of which is capable of subsequent remodelling and modification in light of novel information. Because of the significance of multisensory images to the elicitation of emotional responses, imagery in sport is briefly elucidated here.

Richardson (1999) described imagery as a psychological event which can occur as a personal or phenomenal experience, a mental representation, a property or attribute of materials, or as a cognitive process that is under strategic control. This latter category has meant that athletes' use of imagery has received considerable attention in sport (Conroy, 1997; Cumming & Ste-Marie, 2001; Hall, Rodgers, & Barr, 1990; Lutz, 2001; Munroe, Giacobbi, Hall, & Weinberg, 2000; Munroe, Hall, Simms, & Weinberg, 1998; A. White & Hardy, 1998); and much of this research has been contextualised within Paivio's (1985) conceptual framework, wherein he suggested that imagery's functions could be demarcated into cognitive and motivational dimensions, which can operate at a *specific* or *general* level.

Motivational-General Mastery (MG-M) imagery, for example, has since been associated with being in control, mentally tough and self-confident (Munroe et al., 2000).

Callow, Hardy, and Hall (1998) investigated the effects of a MG-M imagery intervention on the sport confidence of three elite badminton players. The two-week, six-session intervention consisted of imagery associated with confidence, control, and successful management of challenging situations (i.e., MG-M imagery). The intervention enhanced sport confidence for two of the players and stabilized the other players. Callow and Waters (2005) used a multiple-baseline across participants design to investigate the effect of *kinaesthetic* imagery (i.e., drawing on imaged proprioceptive and tactile information) on flat-race jockeys' sport confidence. Three participants completed the State Sport Confidence Inventory (Vealey, 1986) two times a week, prior to a total of 75 races; performance data were also collected. The participants also partook in six kinaesthetic imagery sessions, held twice weekly over a 3-week period. Two of the three participants showed significant increases in their sport confidence as a result of the intervention. Both of these studies conjointly suggest that motivational imagery may be an important outcome from engaging in visual and kinaesthetic imagery. When considering the motivational qualities of music (see Karageorghis et al., 1999), there may conceivably be an additive effect of combining music with such imagery interventions.

2.3 Music

In reference to music listening, Merriam (1964) asserted that "There is probably no other human cultural activity which is so pervasive and which reaches into, shapes and often controls so much of human behavior" (p. 218). Nearly four decades later, Sloboda, O'Neill, and Ivaldi (2001) used the Experience Sampling Method (ESM; Larson & Csikszentmihalyi, 1983) to investigate eight 18-40-year-old non-musicians' everyday experiences with music. Music was audible for 44% of all episodes logged, but was used primarily as an accompaniment to other activities. Sloboda et al.'s (2001) findings also indicated that listening to self-selected music led to increased positivity, greater alertness, and greater focus on the present. North, Hargreaves et al. (2004) sent a daily text message to 346 mobile phone owners for a fortnight; participants were required to complete a music questionnaire about any music they could hear, or had heard since the previous message. More than a third (38.6%) of participants could hear music when the text message arrived, and nearly half (48.6%) had heard music since the previous message, suggesting a high prevalence of music listening in everyday living. Also, the predominant genre was *Chart pop*. Participants chiefly heard music when at home alone late in the evening, had often chosen to listen to the music heard, which suggests a high degree of personal control of music listening.

Contemporary developments in music technology mean we are free to manage our exposure to music more than ever before (M. Bull, 2005). The Moving Picture Experts Group (MPEG) officially formed in 1988 and subsequently developed the MPEG compression system, which includes an audio compression subsystem, called MPEG Audio Layer-3 (MP3). MP3 technology can compress the size of a music track by a factor of 10 or 12, still retain something close to CD quality and enable quick and easy transfer of music from one MP3 device to the next and therefore from one user to another. The growth of peer-to-peer (P2P) communication technology has revolutionised both the music industry and the concept of intellectual property. P2P software allows the user to transfer MP3 files without the need for a regulatory central server (Rojek, 2005). The first service to provide copyrighted music for free over the Internet was Napster. At the height of its popularity, Napster offered its users access to one billion files (Van Hoorebeck, 2003). Napster was swiftly followed by second-generation outlets such as Gnutella, Grokster, iMesh, Kazaa, and Morpheus. Kazaa quickly became the most in-demand service, serving 230.3 million downloads and an uptake of 12 million a month. Now that music is predominantly selected by the user rather than being presented by a broadcaster or educator, it is also perceived as being more neutral and value-free – a property prophesised by Hargreaves and North (1999).

2.3.1 *Music and Young People*

In Western culture, music plays a formative role in offering the security of identification with other like-minded peers (Larson, 1995): A young person who identifies with an artist such as *50 Cent* possesses some degree of unity with millions of other youths worldwide. However, these affiliations can sometimes have deleterious consequences. Hansen and Hansen (1991) performed factor analysis on participants' judgements of *heavy metal* lyrical themes, and identified factors such as drugs and suicide, prostitution, pornography, rape, the devil, war, death, and the occult. There is also evidence that heavy metal music is associated with delinquency in the absence of adequate parental control. For example, Singer, Levine, and Jou (1993) investigated relationships between self-reported rates of offending and the music predilections in a sample of principally white, affluent American high school students. Students who claimed to enjoy listening to heavy metal reported significantly more offences than those who preferred other rock styles. This is supported more recently by Kubrin (2005), who performed content analysis of 403 rap songs spanning the period 1992 – 2000. She found that violence was portrayed in many of the lyrics, and listening to rap music served many functions including establishment of social identity and reputation, and the application of social control. However, such evidence does not necessarily indicate a cause-and-effect relationship; further research is required to elucidate the directionality of this association.

Some contradictory evidence stems from Konecni's (Karno & Konecni, 1992; Konecni, 1984) work. He demonstrated that the messages which artists attempt to communicate through their work are rarely recognised by the perceiver (see also North & Hargreaves, 1998). For example, participants were unable to identify correctly the intended subject of pop music lyrics, even when performers' identities were revealed. Also, re-ordering of movements from Beethoven's quartets and sonatas – thereby reducing the communicative power of the pieces – had little effect on participants' enjoyment (Karno & Konecni, 1992). North and Hargreaves (1997a) found that perceived attractiveness of pop music performers affected the perception of their music. Perceived messages in music, especially enforced by those believed to be in authority, may also affect the listener's subsequent perceptions (North & Hargreaves, 2005).

2.3.2 *Development of Music Preferences*

Gustav Fechner (1876), in his book *Vorschule der Äesthetik*, introduced the concept of experimental aesthetics. He promoted the idea that aesthetic beauty is associated with the absence of extremes – what he termed the aesthetic mean – a concept which has support from contemporary research into facial attractiveness (Baudouin & Tiberghien, 2004; Eisenthal, Dror, & Ruppin, 2006). Daniel Berlyne (1971) developed this concept to form what he called the *new experimental aesthetics* (Berlyne, 1974). He proposed (a) that an inverted-U relationship exists between preference for any given stimulus and its arousal potential (see Figure 2.4), such that moderately arousing stimuli should be the most preferred (cf. Wundt, 1897); and (b) that three categories of stimulus variable mediate the listener's arousal: *Psychophysical variables*, which Berlyne described as intrinsic physical properties of the stimulus such as musical tempo; *ecological variables*, which are classically conditioned associations between the stimulus and other events or activities of biological importance; and *collative variables*, which Berlyne believed to affect the arousal potential of the stimulus; examples of collative properties are complexity and familiarity.

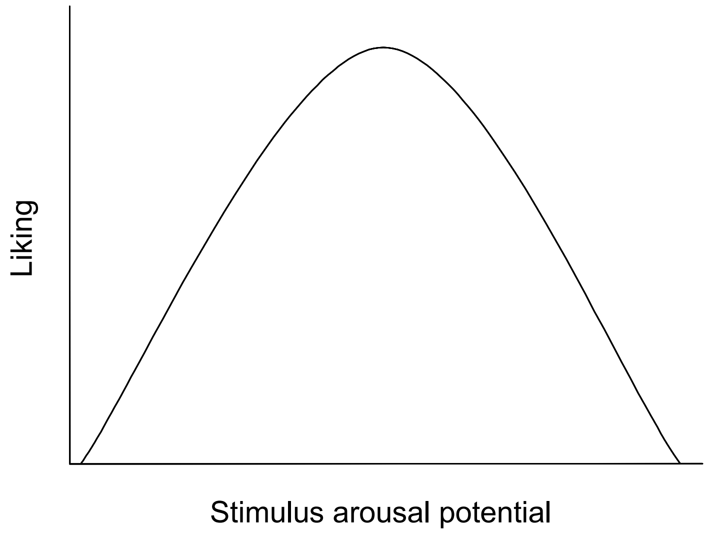

Figure 2.4. The relationship between liking for a stimulus and its arousal potential (adapted from Hargreaves & North, 1997).

Berlyne’s work continues to influence musicological research (e.g., North & Hargreaves, 1997b; Rickard, 2004; Ritossa & Rickard, 2004). However, music listening does not occur within a social vacuum. A wealth of factors contributes to the effect it has on the listener, and considerable research exists that offers contradictory evidence for Berlyne’s (1971; 1974) theory (Martindale & Moore, 1990; Martindale, Moore, & Anderson, 2005; Martindale, Moore, & Borkum, 1990)

Familiarity appears to play a key role in liking for musical stimuli (North & Hargreaves, 1995); people prefer music that reduces their uncertainty about subsequent events. Extremely unfamiliar music does not reduce uncertainty, since the events within it are totally unpredictable to the listener. Very familiar music also does little to reduce uncertainty because it contains very little new information (Hargreaves, 1986), and high perceived complexity tends to result in reduced preference (North & Hargreaves, 1995). However, evidence suggests that familiarity interacts with other collative properties of the stimulus such as complexity (Heyduk, 1975), to mediate arousal potential. Familiarity is also mediated by the degree of media exposure; for example, radio plugging (Erdelyi, 1940; Wiebe, 1940). However, the earlier mentioned developments in music technology have led to wider availability of music, and thus it is increasingly employed as a leisure commodity (North, Hargreaves et al., 2004).

Boyle, Hosterman, and Ramsey (1981) asked 397 students from elementary and secondary schools and three different districts to complete self-report measures. Participants submitted demographic information, the titles of their three favourite popular music selections, and rated the degree to which each of 11 factors was important in determining their choices of music on a 5-point Likert-type scale. Four factors intrinsic to the music were listed as the most influential: *Melody*, *mood*, *rhythm,* and the *lyrics*. Younger students displayed greater similarity in their track preferences, and diversity in preferences appeared to increase with age. Subsequent research has corroborated the implications of J. D. Boyle et al.'s (1981) study, that music not only forms an important part of students' lives (Lamont, Hargreaves, Marshall, & Tarrant, 2003), but offers opportunities for adolescents to express themselves as individuals, and internalise strongly emotive images, around which their personality can develop (Larson, 1995).

An individual's age and the degree to which they have been acculturated to different musical genres seem to affect their ratings of familiarity with musical selections. Hargreaves and Castell (1986) found that liking for obscure folk songs peaked at a later age than did liking for more familiar nursery rhymes: Ostensibly through acculturation, older people had been overexposed to the nursery rhymes, but had had sufficient cultural exposure to develop liking for the less prevalent, obscure songs. Similar developmental effects exist in preferences for common and uncommon words (Colman, Walley, & Sluckin, 1975), and studies of large numbers of participants appear to corroborate the idea that musical preference corresponds closely to the listener's age (LeBlanc, 1991; LeBlanc, Sims, Siivola, & Obert, 1993).

2.3.3 *Emotional Responses to Music*

Our experiences with music are closely linked to its ability to induce emotional responses (Juslin & Sloboda, 2001), despite the fact that musical sequences do not explicitly refer to specific events in the external world in the way that verbal utterances do (Sloboda, 1998). For many people, simply listening to music often results in the experience of pleasure (North, Hargreaves et al., 2004), and musically-induced emotions are not qualitatively or quantitatively different from other experienced emotions (Krumhansl, 1997). Indeed, Damasio (2000) remarked that "…fine human emotion is even triggered by cheap music and cheap movies, the power of which should never be underestimated" (p. 36). Many musicologists would argue that we treat music as intentional and personal, and it is used in the social construction of emotional feelings and displays (Sloboda & O'Neill, 2001).

Juslin and Laukka (2003) conducted a meta-analysis of behavioural and acoustical studies, and concluded that listeners perceive music as expressive of emotions because music mimics vocal expression in speech. Moreover, infants prefer singing to speaking (Nakata & Trehub, 2004), suggesting that music is even more potent in the expression of emotions. Maternal singing is both emotionally engaging and individualised, which suggests that singing may serve to identify a mother to her child (Bergeson & Trehub, 2002). From this perspective, musical effects on emotions may be universal and also unique, depending on individual experience. Indeed, emotional appraisal of music is modulated by prior experience; the *mere exposure effect* (Zajonc, 1980) on musical taste is a well-established phenomenon. We prefer familiar over unfamiliar music, even after a single prior exposure and often without awareness (Peretz, Gaudreau, & Bonnel, 1998).

Nonetheless, Juslin and Sloboda (2001) noted that relatively little research has examined evaluative responses to music, particularly those relating to the emotional impact of the music on the listener. In the same volume, Gabrielsson (2001) reported that positive emotions (e.g., elation, happiness, rapture, and thrill) were dominant in respondents' experiences with music, and that such experiences were influenced by a combination of musical, personal, and situational factors. Zentner and Scherer (2005) highlighted an important distinction that music researchers should make: The difference between *perception* of emotion in music and the *induction* of emotion via music listening. These are very different concepts, for which close attention to methodological detail is crucial.

2.3.3.1 *Mechanisms of Emotion Induction via Music Listening*

Scherer and Zentner (2001) identified three central routes for emotion induction via music listening. The *memory route* may arise from music acting as a potent trigger to recollection of an emotive event, perhaps via subcortical mechanisms resilient to neural rewiring (LeDoux, 1996). *Empathy* implies the listener's ability to deduce the emotions being experienced by the performer; Scherer and Zentner speculated that empathy may be a more likely route for emotion induction when listening to a highly admired performer, or when the music is played in an emotional manner. The final but arguably most pertinent route is *appraisal*, wherein the perceiver evaluates the personal significance of an event for his or her wellbeing according to a number of criteria such as intrinsic pleasantness. Appraisal of pleasantness is an innate response that determines our orientation towards/away from environmental stimuli, including music (Zentner & Kagan, 1996). Scherer and Zentner (2001) also noted two peripheral routes to musically-induced emotion: *Proprioceptive feedback*, whereby emotions can be induced by manipulation of one of its components, which they describe as coupling of internal rhythms to external drivers (cf. rhythm response; Karageorghis et al., 1999); and *facilitating the expression of pre-existing emotions*, which essentially refers to the loosening of emotional control typically exhibited in social contexts (Ekman, 1972).

Scherer (2004) expanded upon Scherer and Zentner's (2001) earlier work in describing the efficacy of music in eliciting *utilitarian* and *aesthetic* emotions, defining the former as "high intensity emergency reactions, often involving a synchronization of many organismic subsystems…driven by the appraisals in the central nervous system" (p. 241). Utilitarian emotions parallel primary emotions, which may arise from triggering of innate dispositional representations (Damasio, 1994). Utilitarian emotions have important functionality in allowing us to adapt to highly consequential life events; for example, the feeling of fear is a manifestation of the fight-flight response to a looming predator. The survival-oriented function of utilitarian emotions contrasts with the diffuse aesthetic emotions, which may only elicit symptoms such as goose bumps, shivers, or moist eyes.

Aesthetic emotions arguably correspond to secondary emotions, which are acquired/learned dispositional representations stemming from cognitive rather than perceptual phenomena (Damasio, 1994); and they may not serve evolutionarily adaptive functions. For example, anxiety is a protracted, watered-down form of fear arising from anticipation of a fearful stimulus, is often considered debilitative in sport, and its accompanying cognitions vary considerably in the lead-up to competition (Hanton, Thomas, & Maynard, 2004). Scherer (2004) noted that aesthetic emotions are appraisals of visual or auditory stimuli in terms of their artistic qualities; this can be contrasted with the *transactional* self-referenced appraisal of utilitarian emotions (cf. Lazarus, 1991) in which the relevance of the stimulus to the organism's survival is appraised.

2.3.3.2 *The Anxiolytic Effects of Music*

Although anxiety can be considered a complex emotion, comprising a number of other simpler discrete emotions (Izard, 1977), the anxiolytic effects of music have understandably drawn a great deal of research interest, not least for its clinical application. Music can reduce individuals' subjective perceptions of anxiety, despite having no calming effect on autonomic activity: Davis and Thaut (1989) examined psychophysiological responses to preferred, relaxing music in eighteen 18-43 years old musically untrained college students. All participants completed the State-Trait Anxiety Inventory (STAI; Spielberger, 1983), and a 7-point Likert-type self-assessment measure of relaxation. State anxiety decreased and relaxation increased across pre- and post-test, but physiological data showed that the music aroused and excited rather than soothed autonomic and muscular activity. Thaut and Davis (1993) subsequently showed that there were no differences in this effect between self-selected and researcher-selected music.

Subjective ratings of affect and heart rate measures indicated that pre-operative anxiety could be reduced by listening to music (Augustin & Hains, 1996); this is also the case for patients diagnosed with acute myocardial infarction (J. M. White, 1992). Relaxing music during gastrointestinal endoscopic procedures did not significantly enhance tolerance of the procedure, but subsequent patient ratings suggested that the procedure was deemed more unpleasant without music (Bampton & Draper, 1997). Patients undergoing colonic sigmoidoscopy exhibited reduced anxiety, as measured by the STAI (Spielberger, 1983), lower heart rates and lower mean arterial pressures when operated upon in the presence of music (Palakanis, DeNobile, Sweeney, & Blankenship, 1994).

Baranson, Zimmerman, and Nieveen (1995) reported that coronary artery bypass graft patients' mood was significantly elevated when they received music therapy during days 2 and 3 post-operation, when compared to a music-and-video condition and rest-only controls. However, no reductions in anxiety were observed, as measured by the STAI (Spielberger, 1983). But heart rate, systolic BP, and diastolic BP lowered over time, which Baranson et al. (1995) interpreted as indicating a physiological relaxation response. However, the anxiolytic effect of music may lie in its capacity to moderate the response to visual stimuli in our environment, as detailed below.

Eifert, Craill, Carey, and O'Connor (1988) conducted two studies, the first of which examined the affective impact of liked and disliked music on participants' evaluation of (previously affectively neutral) Greek letters. After a conditioning procedure in which participants heard either liked or disliked music when viewing a selection of the Greek letters, participants' preferences for the letters were significantly heightened or lessened respectively. However, this effect was considerably lower than in Eifert et al.'s (1988) second study, in which phobics rated their dislike of the object of their phobia (cane toad, green frog, cockroach, or snake) when in its presence; they also completed an Evaluative Adjective List and rated their discomfort on a scale ranging from 1 to 100. Participants exhibited 43.6%, 74.1%, and 42.7% improvements in each measure respectively. Therefore, the presence of environmental stimuli which are evaluated in transactional terms (Lazarus, 1991) may stand to benefit more appreciably from the anxiolytic effect of music; further, this effect may be mediated by a host of factors, including age, type of stressor, musical preferences and experience, and the type of intervention (Pelletier, 2004; Peretti & Swenson, 1974).

2.3.3.3 *Sources of Emotion in Music*

The sources of emotional responses to music are manifold, but Sloboda and Juslin (2001) delineated two broad categories: *Intrinsic* and *extrinsic*.

2.3.3.3.1 *Intrinsic sources*. Intrinsic sources of emotion are the structural characteristics of the music stimulus, such as intensity, tempo, and harmony, which can collectively create, maintain, confirm, or disrupt musical expectations – inducing potent shifts in emotional state. Hevner (1937) carried out one of the earliest examinations of intrinsic sources of emotion in music. He presented musical compositions to university students, who were required to respond by checking those adjectives from a list of 61 which best described what they thought the music was expressing. Participants listened to eight piano compositions, played at both slow and fast tempi. Thirteen compositions were used for studying pitch; two versions an octave apart were played. Slow tempi were perceived as being most expressive of *dignity*, *calmness*, and *sadness*; fast tempi of *happiness* and *restlessness*. High pitch was most expressive of *sprightliness* and *humour*, while low pitch expresses *sadness*, *majesty*, and *dignity*.

Gaston (1951) attempted to classify music according to its function, stating that *stimulative* music has “pronounced percussive sounds and detached rhythms that tend to induce muscular tension and promote physical energy and bodily movement.” *Sedative* music, on the other hand, is music which “lacks percussive elements, is minimally rhythmic or even monotonous in nature, and tends to promote musical relaxation” (p. 43). Gaston postulated that stimulative music tends to have a fast tempo (usually > 130 bpm) and a strong rhythm and is proposed to enhance energy and induce bodily action. Sedative music generally has a slower tempo (usually < 100 bpm), lacks a strong rhythm, has melodic qualities, and is proposed to induce relaxation.

Kellaris and Rice (1993) asked 52 volunteers to provide affective ratings of three different versions (two slow and one moderately fast) of a classical music composition, played at intensities of 60 dB (soft) and 90 dB (loud). Intensity had a significant effect on affective response insofar as quieter tracks were perceived as more pleasant than louder ones; tempo manipulation yielded no such effect. The authors provided a manipulation check to gauge the likelihood of each participant listening to each variant of the track again; this measure was positively correlated with valence of the affective response. However, this measure did not distinguish between the different versions, as the original composition was identifiable in each.

Sloboda (1991, 1992) pinpointed some structural characteristics that appear to be associated with the induction of bodily and behavioural manifestations of emotion, such as weeping or thrills (cf. Goldstein, 1980): syncopations, enharmonic changes, melodic appoggiaturas; and other theoretical musical constructs which collectively either maintain, create, confirm or interrupt the listener's musical expectations. Structural qualities can also interact to mediate the listener's emotional responses. For example, Webster and Weir (2005) examined the interactive effects of mode (major vs. minor), texture (nonharmonised vs. harmonised), and tempo (72, 108, and 144 beats per min) on listeners' experienced emotions. One hundred and seventy-seven college students rated musical phrases on continuous happy-sad scales. Major keys, non-harmonized melodies, and faster tempi were associated with happier responses, whereas their respective opposites were associated with sadder responses. The effects of the music were also moderated by gender and participants' musical experience. However, it should be noted that Holbrook and Anand's (1990) earlier findings indicated that, when provided with a broad range of tempi, participants' preferences approximate an inverted-U relationship; in other words, preference drops off at higher reaches of the tempo spectrum. Webster and Weir's (2005) musical excerpts were only brief, but Bigand, Filipic et al.'s (2005) research suggested that musically untrained listeners may only require one second to detect the emotional content of a musical selection, the arousal component of which may be most strongly mediated by loudness and tempo (Schubert, 2004).

The arousal potential of music is also related to the listener's uncertainty. Specifically, segments of a musical excerpt which violate the listener's expectations will lead to greater arousal than those which do not (Meyer, 1956). Indeed, subsequent research supports the hypothesis that musical structure affects emotional responding (Sloboda, 1991), and the ability of music and its physical components to elevate or depress the listener's psychophysiological state continues to play a key role in psychomusicological research (Rickard, 2004; Ritossa & Rickard, 2004).

Balkwill and Thompson (1999) asked 30 Western participants to rate the degree of joy, sadness, anger, and peace in 12 Hindustani raga (classical Indian music) excerpts – a genre which was likely to be unfamiliar to all participants. Each participant rated the four psychophysical variables of *tempo*, *rhythmic complexity*, *melodic complexity*, and *pitch range*. Participants were sensitive to joy, sadness, and anger, and their judgements of emotion were significantly related to judgements of psychophysical dimensions, and, in some cases, to instrument timbre. Balkwill and Thompson (1999) concluded that there is a trade-off between the effects of psychophysical variables and extrinsic variables such as acculturation.

2.3.3.3.2 *Extrinsic sources*. *Extrinsic* sources of emotion are psychological in nature, probably arising through one of Scherer and Zentner's (2001) central routes, and may be *iconic* or *associative*. Iconic sources of emotion derive from resemblance between the musical structure and some other agent carrying an emotional tone. For example, high intensity (loudness) and fast tempo imply high-energy and arousal, and may therefore suggest a high-arousal emotion such as excitement, while slow and quiet music may be more indicative of relaxation. Associative sources of emotion in music are arbitrarily formed through associative learning – oftentimes via single-trial conditioning – such that a music track becomes inextricably bound to the often strongly emotive event (Gabrielsson, 2001). Sloboda and Juslin (2001) suggested that extrinsic sources are better determinants of the emotional content (e.g., positive or negative), whilst intrinsic sources are better sources of the emotional intensity – which could determine the expression of *elation* instead of *happiness*, for example.

Research on extrinsic sources of emotion in music is minimal, perhaps owing to the fact that these sources are very idiosyncratic by nature, rendering experimental control problematic. However, Peretz et al. (1998) showed that exposure and familiarity can affect preference for music selections, as well as recognition of the same pieces. Familiarity was positively correlated with the majority of the pleasant emotions, and negatively correlated with the unpleasant emotions of unsettling and disconcerting. This is not surprising given that people who find a song pleasant are more likely to listen to it repeatedly and become familiar with it (Ritossa & Rickard, 2004). Further, our music preferences may not always be conducive to optimal physical performance. For example, Mornhinweg (1992) investigated the effects of three different styles of music (Baroque/Classical; "Popular"; and "New Age") on stress reduction; New Age music and Baroque music reduced heart rate and increased perceived relaxed state relative to music which participants had classified as "popular".

Karageorghis and Terry (2001) suggested the use of music as a conditioned stimulus (CS) in combination with hypnotic suggestion (unconditioned stimulus, US) to develop an appropriate competitive mindset in vivo; this does not, however, appear to have been the subject of empirical investigation. Qualitative evidence comes from Gluch's (1993) interviews of six competitive athletes. The potency of music in evoking memories or previous good performances is aptly illustrated by the following participant quote: "The words in the Hank Williams, Jr., song just trigger me. They remind me of all the work that I've put into getting here" (p. 46).

2.3.3.4 *Using the Circumplex Model to Measure Affective Responses to Music*

North and Hargreaves (1997b) used a modified version of Russell's (1980) circumplex model, which incorporated Berlyne's (1974) model of aesthetic response, to link specific emotions expressed in music to the circumplex model's pleasantness and arousal dimensions. Pivotally, North and Hargreaves substituted *liking* for pleasantness. One group of participants were asked to rate musical excerpts on the extent to which they expressed specific emotions, whilst a second group rated the same excerpts for arousal potential and likeability. The ratings from the first group correlated with those from the second, to lend support to the idea that the emotional response to a piece of music can be determined by these dimensions.

Ritossa and Rickard (2004) also provided support for use of the circumplex model to measure musically-expressed emotions. Participants were required to rate four music tracks which had been selected to collectively represent the four quadrants of the circumplex model, on 11-point scales designed to assess the degree to which the tracks represented each of eight emotions: *Relaxing*, *peaceful*, *exciting*, *festive*, *unsettling*, *disconcerting*, *boring*, and *unstimulating*. Pleasantness, familiarity, and arousal were all useful predictors of emotions expressed in music. Moreover, arousal was predictive of all eight emotions. Arousal is an important dimension in many theories which seek to explain emotional responses to music (Berlyne, 1974; Meyer, 1956; North & Hargreaves, 1997b; Rickard, 2004; Thaut, 1990); and familiarity has previously been identified by North and Hargreaves (1995) as an important moderator of liking for music. Ratings for liking lacked any real predictive value, which contradicted North and Hargreaves' (1997b) earlier finding. However, Ritossa and Rickard's observation may indicate that the listener is able to dissociate themselves from the context of the listening situation, to recall their more typical responses to the music heard. Explicitly, pleasantness may be an affective judgement, whereas liking is not; this arguably finds some support from research into adolescents' liking for musical idioms that one would otherwise consider to be representative of highly unpleasant components of emotional states (e.g., aggression, Kubrin, 2005).

Collier (2007) examined the utility of the circumplex model in identifying musically-induced emotions, noting that "In the scaling of emotions in general, and their application to music in particular, the valence (good/bad) and activity or arousal dimensions are ubiquitous" (p. 110). Collier conducted five studies to demonstrate that music is capable of expressing a greater range of emotions than can be depicted by these two dimensions. Participants ranked sets of emotions with regard to how well they applied to short unfamiliar instrumental selections. They could do so rapidly, with significant reliability, even when participants were required to identify subtle emotion distinctions – both independent of, and within, each of the two dimensions. Thus, although the circumplex model is undoubtedly an expeditious measure for assessing musically-expressed emotions, consideration should be given to the selection of accompanying categorical descriptors, if subtle distinctions are necessary. One further caution should also be noted: The foregoing studies have focused on using circumplex-based measures to assess the emotions *expressed* in music; measurement of the listener's affective *experience* when listening to music is lacking.

2.3.4 *Neurophysiological Correlates of Music Listening*

2.3.4.1 *Perceptual Phenomena*

2.3.4.1.1 *Mechanisms of auditory perception*. Gates and Bradshaw (1977a) were among the first to identify cerebral asymmetries in the processing of music through examining differences in perception between the ears. The left ear was faster (reflecting the efficient emotional processing of the right hemisphere), but the right ear was more accurate (reflecting the left hemisphere's specialisation for processing musical and linguistic structure). Gates and Bradshaw (1977b) reviewed the existing literature, and concluded that the left hemisphere is probably implied in assessing structural components of music.

Nearly three decades on, Levitin and Menon (2005) used fMRI to compare participants' neural responses to Beethoven's *Für Elise* and a scrambled version of the same piece. The scrambled concatenation exhibited the same spectral profile and power as the original, but the temporal structure and associated listener's expectancies no longer existed as a result. Levitin and Menon proposed that the differences witnessed in activations should therefore index the neural processes associated with the perception of musical structure. In validation of the successful matching of acoustical features for the two conditions, there were no significant activation differences in primary or secondary auditory cortices. However, there were significant activations for the music condition in not only emotion-processing (e.g., anterior cingulate cortex) and brainstem structures, but also in the pars orbitalis area (Brodmann Area 47) of the frontal cortex, suggesting that the processing of language and music share common neural substrates. Levitin and Menon could not explain the significant activations witnessed in precuneus, visual cortices, posterior cingulate, and inferior temporal gyrus, but these predominantly visual activations may reflect a disturbed state in which the individual's attentiveness to the environment is heightened.

2.3.4.1.2 *Expert-novice differences*. A related factor for consideration in future when investigating neurophysiological responses may be musical expertise. Wagner (1975) reported that musicians' and non-musicians' neural alpha wave activity levels differed markedly when listening to two musical selections, and this did not correspond to reported increases in attentiveness. However, McElwain (1979) found significantly more alpha activity in the right temporal lobe of non-musicians, compared to significantly more alpha activity in the left temporal lobe of musicians when listening to music; the right temporal lobe is predominant in processing emotional content of auditory information (e.g., Alfredson, Risberg, Hagberg, & Gustafson, 2004), whereas the left temporal lobe primarily processes structural properties (e.g., tempo; Schonwiesner, Rubsamen, & von Cramon, 2005). Bigand, Vieillard, Madurell, Marozeau, and Dacquet's (2005) examined musically trained and musically untrained listeners' ability to differentiate music excerpts according to emotional meaning. Their results showed that both groups organised the excerpts similarly; there was only a minor effect of expertise on this ability. Importantly to the present thesis, these categories could be explained by two primary dimensions of arousal and valence.

There may be few differences between musically trained and musically untrained persons' neural responses to music, whether the listener is required to be analytic or spontaneous (McElwain, 1979). Morrison, Demorest, Aylward, Cramer, and Maravilla (2003) showed that neural activation during recall of music excerpts is similar among experts and nonexperts, even when the recall performance for the musical selections varied. This occurred irrespective of cultural familiarity with the music. Minor evidence is also emerging to suggest that some areas of the brain are dedicated to processing various components of music (Peretz & Zatorre, 2005; Zatorre & Peretz, 2001); for example, temporal structure and expectancies might have neural loci (Levitin & Menon, 2005).

2.3.4.2 *Emotion-related phenomena*

Our preference for consonant over dissonant music appears to be innate (Zentner & Kagan, 1996), and people automatically associate the major and minor modes with happy and sad emotions respectively (Dalla Bella, Peretz, Rousseau, & Gosselin, 2001). Samson and Peretz (2005) examined the relationship between music liking and prior exposure in patients with damage to brain structures implicated in memory (e.g., the hippocampus) and emotions (e.g., the amygdala). They found that memory and preferences are tightly connected, making music memorable despite the presence of severe memory losses in other domains. In recent years, emotion neurophysiology researchers have been increasingly harnessing music's capacity to elicit measurable emotional responses (Blood & Zatorre, 2001; Blood, Zatorre, Bermudez, & Evans, 1999; Brown, Martinez, & Parsons, 2004; Koelsch, Fritz, von Cramon, Müller, & Friederici, 2006; Menon & Levitin, 2005).

Although our emotional responses to music may be conditioned by memory (Zentner & Scherer, 2005), the ability to recognise the emotional character of musical excerpts is remarkably consistent across listeners, independently of music education (Bigand, Filipic et al., 2005). Further, as Bigand, Filipic et al. point out, the emotional appraisal of subtle structural aspects of music can be immediate. Less than a quarter of a second of music is sufficient to elicit reliable emotional judgements (see also Peretz, Gagnon, & Bouchard, 1998), and affective responding to music begins early in the postnatal development of the newborn child (Schmidt, Trainor, & Santesso, 2003). Extremely fast-acting processes are typically observed in response to biologically important stimuli. The fact that short musical extracts can arouse emotional responses similarly in every human being with rapid onset and with little awareness qualifies such experiences as reflexes. Translated in neural terms, the characterization of musical emotions as reflexes need not be assimilated to subcortical or primitive reflexes.

As reviewed by Koelsch (2005), all available neuroimaging data point to the involvement of the neocortex (e.g., the orbitofrontal cortex, an evolutionary recent brain structure), in addition to the classical limbic structures (e.g., the amygdala) in the emotional appraisal of music. As developed further by Koelsch, the contribution of this frontal area is highlighted by the temporal dynamics of music that offer departure points from expectancies, thereby creating tension and relaxation, an emotionally appealing feature of music (Meyer, 1956). The time course of the emotions experienced is an important aspect that can be easily monitored with music, as emphasised by Bigand et al.(2005) and Koelsch (2005). Yet, dynamic stimuli are rarely used in studies of the emotional brain. Emotions are typically triggered by static stimuli, like the widely-used set of images of the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1997).

The emotional response to music has now been accepted to such an extent that music is being specifically employed in order to investigate emotion processing structures (Koelsch et al., 2006). Music provides a unique window for studying the operation of the emotional brain at both the cortical and subcortical levels. The fact that musical emotions can act at the subcortical level, by triggering the limbic system, an evolutionarily ancient brain structure, is also of primary importance. Under certain circumstances, music can access neural substrates that are associated with either primary reinforcers, such as food and sex (Blood & Zatorre, 2001), or with anticipation of danger (Gosselin et al., 2005). Thus, with limbic mediation, musical emotions resemble other important classes of biological stimuli. Whether music is unique in this respect remains to be seen; it may be one of a class of human constructs that elicits pleasure by co-opting ancient neural systems via inputs from the neocortex. In this respect, music serves as an excellent means by which we can explore the interactions between neocortically-mediated cognitive processes and subcortically-mediated affective responses.

Menon and Levitin (2005) compared the neural responses of six participants to 23-second excerpts of music with neural responses to 23 s compilations of the same music, presented in concatenated 250-350 ms chunks. This methodological approach was taken to ensure that all auditory stimuli retained the same distribution of loudness and pitch. Participants showed increased activation during music listening in three interrelated structures. Specifically, the nucleus accumbens (NAc), a pleasure centre in the brain; the hypothalamus, an essential modulator of autonomic responses; and the ventral tegmental area, a part of the mesolimbic dopaminergic pathway – one of the midbrain-diencephalic axes which help to maintain our general arousal levels – were all activated. Menon and Levitin's subsequent functional connectivity analysis of these areas identified a strong positive relationship between the three, thereby implicating the reciprocity of their interconnections. In a related positron emission tomography (PET) study, activation in the ventral striatum was correlated with the intensity of pleasurable responses to music (Blood & Zatorre, 2001), but PET lacks the spatial resolution to image the nucleus accumbens and consequently no focal activation had previously been reported there. Menon and Levitin (2005) noted that their study corroborated Blood and Zatorre's (2001) findings, but also extended them through demonstrating involvement of the nucleus accumbens itself. The significant activation in the hypothalamus may reflect the fact that listening to music is often accompanied by changes in autonomic responses (Blood & Zatorre, 2001; Goldstein, 1980; Krumhansl, 1997), giving rise to subjective reports of ''thrills'' (Goldstein, 1980) and ''chills'' (Blood & Zatorre, 2001).

Psychophysiological responses to auditory stimuli may also be mediated by the listener's personality: Martindale, Anderson, Moore, and West (1996) found that individuals whom they had previously classified as creative displayed higher amplitude of skin potentials (a measure of sympathetic activity, and consequently emotional arousal) in response to 20 bursts of white noise played at 60 dB; they also habituated at a slower rate than less creative participants. These findings have since been corroborated with EEG and cardiovascular data. For example, Kallinen and Ravaja (2004) examined whether personality moderated the influence of a music listening session comprising 12 music pieces, on 32 participants' self-report and psychophysiological measures of emotion. EEG and cardiovascular (inter-beat intervals and pulse transit time) activity was recorded continuously during 60 s eyes-open and 60 s eyes-closed resting periods before and after music listening. Participants rated their mood immediately after the pre-music and post-music rest periods. Both self-report and cardiovascular measures indicated the greatest increases in activation from pre- to post-music rest period occurred in highly neurotic and anxious participants. Increased activation during music was partially supported by decreased overall whole-brain EEG theta activation and by increased overall EEG alpha activation in participants classified as highly neurotic.

2.3.5 *The Effects of Music on Behaviour*

Evaluative conditioning (Martin & Levey, 1978) is the process whereby a neutral stimulus, after pairing with either a positively or negatively valenced stimulus, takes on the valence of that stimulus. Evaluative conditioning has undergone considerable investigation in recent socio-cognitive research (Field & Moore, 2005; Hammerl & Fulcher, 2005; Lipp, Oughton, & LeLievre, 2003; Lipp & Purkis, 2005; Meersmans, De Houwer, Baeyens, Randell, & Eelen, 2005; Walther, Nagengast, & Trasselli, 2005; Wills, 2005). Importantly, it is a process that can occur without conscious awareness (Dijksterhuis, 2004; Field, 2000; Zajonc, 1980). In the context of music and marketing, for example, unattended background music can serve as the unconditioned stimulus (UCS), inducing a conditioned response to a previously relatively neutral product; the end result is that the consumer may choose that product over another rival (Gorn, 1982); this need not happen at a conscious level (Tom, 1995).

Bruner (1990) conducted a review of mood manipulation with music in marketing contexts, and drew three broad conclusions: Human beings non-randomly assign emotional meaning to music; they experience non-random affective reactions to music; and music used in marketing-related contexts is capable of evoking non-random affective and behavioural responses. The use of music as a conditioning medium in marketing contexts has since become widespread. Alpert and Alpert (1990) tested the effect of happy and sad music on three groups of participants' moods and evaluations of three greetings cards, which had been randomly matched with happy or sad music, or with no-music playing. Participants' mood was measured during exposure. Participants showed a preference for the greetings cards which had been paired with happy music, when compared to those paired with sad music. Music that has previously been associated with an unpleasant emotional experience can subsequently act as the UCS in modifying attitudes towards a brand of product in both the visual modality (Blair & Shimp, 1992), and on the radio (Zander, 2006). Music can reinforce cultural messages (Hung, 2001); it can also interact with cognitive aspects of personality (Zhu & Meyers-Levy, 2005). Eifert et al. (1988) successfully used music classed by participants as *highly liked* to improve their evaluation of previously neutral Greek letters, and to ameliorate phobics' evaluation of previously aversive stimuli such as spiders.

Athletes' emotional states can vary through the duration of a competition (Butt et al., 2003), and interpretation of anxiety symptoms may be mediated by an athlete's self-confidence (Hanton, Mellalieu et al., 2004). Implicitly activated emotional states may also mediate subsequent cognitive processes (Niedenthal & Showers, 1991). Therefore, music may serve as a potent (unconscious) mediator of athletes' emotional states. Indeed the capacity of music to enhance perception of video images has been successfully exploited in sport: Templin and Vernacchia (1995) created music highlight videos to investigate the effects on the shooting performance of collegiate basketball players; three of the five participants displayed a mean increase of 4.7 % in overall field goal percentage. But Templin and Vernacchia (1995) acknowledge that causality is difficult to attribute in this instance. Nonetheless, strong evidence continues to accumulate for the capacity of music to mediate the physiological and affective response to visual images (R. J. Ellis & Simons, 2005), to moderate observers' attitudes towards characters in films (S. K. Marshall & Cohen, 1988), and to enhance the neural response to emotive pictures (Baumgartner, Esslen, & Jäncke, 2006; Baumgartner, Lutz, Schmidt, & Jäncke, 2006).

North and Hargreaves (1996) examined the effects of music on consumers' responses to a dining area, using music selections which varied in their complexity and style. Participants' views of the dining area were concomitant with the responses to the music played. North, Shilcock, and Hargreaves (2003) looked at the effects of classical music, pop music and no-music on consumer spending patterns in a British restaurant over a period of 18 evenings. Classical music in the background led to people reporting that they were prepared to spend more, and also led to higher spending overall. There is also evidence that people are more likely to invest time and effort in the help of others after listening to uplifting, as opposed to annoying, music (North, Tarrant, & Hargreaves, 2004).

2.3.6 *Music and Imagery*

Osborne (1981) asked 43 participants to listen to synthesised music under relaxed conditions, and to write down their responses. Data were content analysed into thoughts, emotions, sensations and images. Osborne concluded that imagery was the dominant mode of response to music listening. Quittner and Glueckauf (1983) found that music was a potent elicitor of imagery when compared to either progressive relaxation or a no-treatment control. The effectiveness of music in eliciting imagery was shown in ratings of vividness, ease of evocation, and time spent imaging. Quittner and Glueckauf (1983) also assessed brain alpha activity, but no differences were observed. The authors remarked that the capacity to image is essential for the successful outcome of systematic desensitization (Wilkins, 1972), and covert conditioning (Cautela, 1971), a mental health treatment that uses the behaviour modification principles to enable people to improve their behaviour or inner experience. Quittner and Glueckauf's (1983) results were replicated to some extent by Tham (1994), who reported significantly higher movement imagery vividness for music-plus-imagery groups when compared to a no-music control group.

2.3.6.1 *Guided Imagery with Music*

Guided Imagery with Music (GIM), most notably the Bonny Method (Bonny, 1989), has become a popular alternative in palliative care. The Bonny Method is a process focusing on the conscious use of imagery arising in response to a formalised programme of relaxation and classical music, although Bonny (1989) did not specify precisely what music should be used, nor how it exerts its effects. Nonetheless, GIM has been used successfully to reduce depression, fatigue, and to alleviate total mood disturbance, as identified by the POMS (McNair et al., 1971), and blood cortisol levels (McKinney, Antoni, Kumar, & Tims, 1997). Burns (2001) explored the effectiveness of the Bonny Method in alleviating mood disturbance and improving quality of life in cancer patients. Eight volunteers with a cancer history were randomly assigned to either an experimental or a waiting list control group. Experimental participants took part in 10 weekly GIM sessions. All participants completed the POMS (McNair et al., 1971) and Quality of Life-Cancer (QOL-CA; Padilla, 1983) questionnaires pre-test, post-test, and at a 6-week follow-up. Individuals participating in GIM sessions displayed improvements in mood and quality of life scores at post-test than control participants. Additionally, mood and quality of life scores continued to improve in the experimental group, even after sessions were complete. Burns contended that GIM was effective in improving mood and quality of life in these cancer patients.

2.3.6.2 *Auditory Imagery*

Auditory imagery is “hearing in the mind’s ear” (A. P. Moran, personal communication, September 5, 2005), and represents an exciting new direction in applied sport psychology imagery research. Much of previous research has been directed at the visual (Munroe et al., 2000) and kinaesthetic (N. Callow & Waters, 2005) modalities. Researchers have used both functional magnetic resonance imaging (fMRI, Yoo, Lee, & Choi, 2004) and positron emission tomography (PET; Halpern & Zatorre, 1999) to identify brain structures involved in auditory imagery for monotonic (single tone) stimuli and familiar melodies, respectively. Participants in both studies exhibited increased activity in the superior temporal gyrus, the location of primary auditory cortex. Kraemer, Macrae, Green, and Kelley (2005) found that during periods of silence interspersed amongst both familiar and unfamiliar tracks, significant activity occurred in participants’ auditory association cortex, and that this activity was enhanced when they listened to familiar tracks; activation also increased significantly in primary auditory cortex during gaps in familiar instrumental-only tracks, when compared to those with lyrics. Therefore, auditory imagery may be a powerful means of transporting oneself away from the immediate environment, perhaps as an active attentional manipulation strategy.

2.3.6.3 *Music and Imagery in Sport*

Aside from the use of music videotapes, which has proven to be a most effective technique for building confidence in sport (Templin & Vernacchia, 1995), the use of music in facilitating imagery in sport has received very little attention. One notable exception is a study by Dorney, Goh, and Lee (1992), who compared the effect of imagery to imagery and music as preparation strategies for a muscular endurance task. Performance in the task improved equally across both groups, but the imagery and music group exhibited higher heart rates prior to performance. Dorney et al. concluded that music might have affected arousal as a result of imagery, but that there was no corresponding effect on muscular endurance performance.

Gluch's (1993) interviews with six National-level US athletes yielded some qualitative data relating to the athletes' use of music as an imagery inducer, to complement Osborne's (1981) earlier results with undergraduates. Participants used music along with imagery to "see" themselves performing in the upcoming competition, or to help them recall a previous competition in which they had performed well. Gluch (1993) cites the example of a baseball pitcher who used a certain song as a trigger to evoke memories of what he considered his "peak performance". The same athlete said "Sometimes I'll picture myself being the pitcher who strikes out Roy Hobbs [in the movie *The Natural*]. I love listening to that music because it's already associated with baseball" (p. 47).

Blumenstein, Bar-Eli, and Tenenbaum (1995) randomly assigned 39 college students to three treatment groups (autogenic plus imagery training; music plus imagery training; autogenic, music and imagery training), one placebo group, and a control group. Imagery was related to a 100-m sprint. Treatment and control conditions each comprised 13 sessions of 20 min duration. During the first seven sessions, participants in the treatment groups underwent 10 min of relaxation followed by 10 min of excitation. During the last six sessions, similar treatment was provided accompanied by frontalis EMG biofeedback. Heart rate, galvanic skin response, EMG and breathing frequency were recorded at three points during each session. In addition, an athletic task (100 m run) was examined at the outset, after seven sessions (no biofeedback) and after an additional six sessions (with biofeedback).

Biofeedback was found to have a significant augmenting effect on physiological components and athletic performance when accompanied by autogenic, music and imagery training.

2.4 The Psychophysical Effects of Music on Human Performance

Lucaccini and Kreit (1972) conducted a review of the literature relating to the psychophysical and ergogenic effects of music in sport and exercise. They found that, since the early twentieth century, researchers had demonstrated an effect of music and its elements upon mood (Hevner, 1937); physiological responses, such as galvanic skin response (Zimny & Weidenfeller, 1963); and the facilitation of learning physical skills such as throwing and catching (Beisman, 1967). However, they found a paucity of evidence to suggest that music improves athletic performance; the majority of studies yielded no effect.

Karageorghis and Terry's (1997) later review highlighted considerable progress: They found evidence to suggest that synchronisation of submaximal exercise with musical accompaniment can increase work output (Anshel & Marisi, 1978); listening to sedative/relaxing music can reduce the rate of perceived exertion (RPE) during submaximal exercise (Copeland & Franks, 1991); and lively music can enhance affective states at both medium and high levels of work intensity (Boutcher & Trenske, 1990). Karageorghis and Terry proposed four mechanisms through which music might have a psychophysical effect in sport and exercise: (a) the reduction of sensations of fatigue; (b) amelioration of mood state; (c) changes in psychomotor arousal; and (d) the promotion of synchronization.

Karageorghis and Terry (1997) also identified a number of limitations to earlier research, in their review. Importantly, they highlighted researchers' failure to detail not only the music selection and usage criteria, but also the intensity (volume) at which music was played; Karageorghis and Terry remarked upon the capacity of intensity to influence the listener's reactivity to music, which may be mediated by both the timing and mode of delivery (e.g., headphones vs. loudspeakers). Also pertinent to the present research programme is their suggestion that (a) only one musical idiom should be employed when addressing the effects of tempo on performance variables, and (b) motor tasks used to obtain dependent measures should be capable of being standardised, in order to allow subsequent replication.

2.4.1 *Affective Consequences*

Boutcher and Trenske (1990) asked 24 female participants to perform three 18-minute sessions on an ergometer at 60% (light), 75% (moderate) and 85% (high) of maximal heart rate, while RPE, affect and heart rate were measured using the Borg scale (Borg, 1971), Rejeski's (1985) 10-point bipolar scale and an electrocardiogram respectively. Each participant completed three trials with music, no-music (control) and a sensory deprivation condition, in which they were required to wear earplugs and opaque goggles. Music lowered participants' RPE only in the low workload condition when compared to the deprived state, the RPE rating for which was significantly higher than for the control (silence) condition at moderate workload. At the moderate workload, music induced significantly more positive affect than both silence and deprived conditions; this effect extended to the high workload condition when comparing to deprivation only. Boutcher and Trenske (1990) interpreted their results in terms of Rejeski's (1985) adaptation of a parallel processing model, which suggests that when individuals are working at near-maximal levels, physiologically salient cues will predominate, increasing the overall perception of effort.

Copeland and Franks (1991) investigated the effects of different types of music on 24 participants' heart rate (HR), RPE and time to exhaustion while working to exhaustion on a treadmill run/walk test while wearing headphones. The three treatment conditions comprised *Type A*, high intensity (5 dB above treadmill noise), upbeat, and fast (approximately 140 bpm) popular music; *Type B*, low intensity (10 dB below treadmill noise) easy-listening and slow (100 bpm approx.) popular music; and a no-music control condition. HR was recorded via ECG at 30 s intervals until volitional fatigue, and RPE was obtained after the test, for five different points during the test. Their results suggested that soft, slow music may decrease both physiological and psychological arousal during submaximal exercise and lead to increased endurance performance when compared with silence. Seath and Thow (1995) found similar reductions in RPE and affect, using Borg's scale (Borg, 1971) and the Rejeski Feeling Scale (Rejeski, 1985) when they played background music to 34 physiotherapy students during their physical training sessions, twice weekly for 6 weeks. Therefore, listening to music may be effective at lower intensities in mediating affective responses to exercise. It is noteworthy, however, that Copeland and Franks (1991) used a very small sample size, a between-groups design, and a significance level of 0.10, all of which reduce the statistical power of their study considerably (Tabachnick & Fidell, 2006).

The concept of attention during physical performance is an important one: Pennebaker and Lightner (1980) reported two studies, the first of which required that participants run on a treadmill in one of two conditions (a) while hearing an amplification of their own breathing, and (b) hearing distracting sounds; the latter group reported less fatigue and fewer symptoms of fatigue. In the second study, participants ran each of two equal length cross-country and athletics tracks. The cross-country course required greater attention to the external environment. Times were faster on this course, but self-report of symptoms of fatigue were comparable across the two. Pennebaker and Lightner (1980) interpreted these results in terms of attentional shifting to more performance-relevant cues, in line with Rejeski's (1985) model.

The efficacy of music as a listening strategy may therefore be a function of *competition for resources*; music which actively competes for an athlete's attention may be a more effective strategy. Research by Johnson and Siegel (1987) indicates that this is the case. Twenty-six female participants performed exercise at either 60% or 90% of predicted $\dot{V}O_{2max}$

for 5 min, and concurrently solved arithmetic problems (active attentional manipulation), listened to music (passive), or did nothing (control). Participants completed a bespoke measure of attentional direction, the Physical Activity Questionnaire (PAQ; Kinsman, Weiser, & Stamper, 1973) and the Borg RPE scale (Borg, 1962). Both active and passive conditions reduced perceptions of fatigue on the PAQ, but the active manipulation was more effectual at 90% of $\dot{V}O_{2\ max}$; this may be explained by the fact that the autonomic response is augmented slightly as a result of performing mental activity during physical exertion (Szabo, Péronnet, Gauvin, & Furedy, 1994).

Whether music is successful in diverting attention from painful stimuli appears to be a function of the pain sensations arising from the competing stimulus (e.g., physical exercise), and this has been examined in a clinical setting. For example, MacDonald et al. (2003) conducted two studies to investigate the effect of listening to self-selected music on postoperative anxiety and pain perception. Following minor foot surgery, participants in a music condition displayed significantly lower postoperative anxiety than a control group despite the fact that perception of pain remained the same. However, the effect disappeared when the same experimental conditions were examined for two groups who were in recovery from total abdominal hysterectomy; this was arguably a more invasive procedure than the foot surgery.

The emotive content of passive manipulations may be another variable of interest: White and Potteiger (1996) compared three passive attentional manipulations on 24 physically active college students' ratings of RPE during exercise under four different conditions. Thirteen men and 11 women carried out four 20 min periods of cycling at 70% of their peak aerobic power under auditory (listening to upbeat music played at 140-145 bpm), visual (viewing high-action videotape of human stunts with no auditory stimulation), auditory/visual (both stimulations), and control (quiet, visually sterile) conditions. The researchers measured participants' HR via telemetry, and obtained scores for peripheral RPE (as gauged by the feeling in leg joints and musculature), central RPE (as gauged by cardiovascular and pulmonary sensations), and overall RPE (a combined measure) at 5 min intervals. Peripheral RPE was rated as significantly higher during the visual condition at 5 and 20 min compared with the auditory/visual condition and at 5 min compared to auditory stimulation. Central RPE was significantly higher for visual stimulation at 5, 10, 15, and 20 min compared with auditory/visual, at 5, 10, and 20 min compared with auditory, and at 5 min compared to the control condition. Overall RPE was significantly higher for visual stimulation at 5, 10, 15, and 20 min compared with auditory/visual and at 5 and 10 min compared with auditory stimulation. White and Potteiger concluded that passive dissociations using high-action visual images may evoke a strong, emotional response which, in turn, may heighten awareness of physical sensations. It also worthy of note that the music appeared to modulate participants' responses to the images viewed, such that statistically significant differences emerged. This effect has since been evinced by neurological investigation (Baumgartner, Esslen et al., 2006; Baumgartner, Lutz et al., 2006).

Abadie, Chance, O'Nan, and Lay (1996) found no significant effects of music on perceived exertion when they asked 30 male participants to cycle on an ergometer at a workload of 122.5 W in each of two conditions: While viewing videotapes with musical accompaniment, or in quiet conditions. However Abadie et al. did not ascertain their participants' fitness levels. Therefore, no measure of relative workload such as $\dot{V}O_2$ was available; this has been an important feature of other studies (Johnson & Siegel, 1987; V. B. White & Potteiger, 1996).

The majority of music in the studies cited above was researcher-selected, which may be an important omission, given the possible link between self-selected music and physiological arousal (Davis & Thaut, 1989). Indeed, Lucaccini and Kreit (1972) suggested that familiarity plays a crucial role in moderating the influence of music on arousal level. The assignations of *upbeat*, *lively*, and *stimulative*, for example, have also been made with little justification, in a seemingly random fashion (Karageorghis et al., 1999). In light of this, Karageorghis et al. (1996) suggested that researchers investigate whether self-selection of music influences psychophysical responses.

2.4.2 *Motivation*

In order to more accurately assess the motivational qualities of music when used in exercise and sport domains, Karageorghis et al. (1999) developed a conceptual model (Figure 2.5), to form a foundation for the Brunel Music Rating Inventory (BMRI). Respondents to the BMRI rate each of 13 items, which collectively assess intrinsic (e.g., *tempo*) and extrinsic factors (e.g., *association of music with sport*) deemed to contribute to the motivational qualities of music, on a 10-point scale ranging from 1 (not at all motivating) to 10 (extremely motivating).

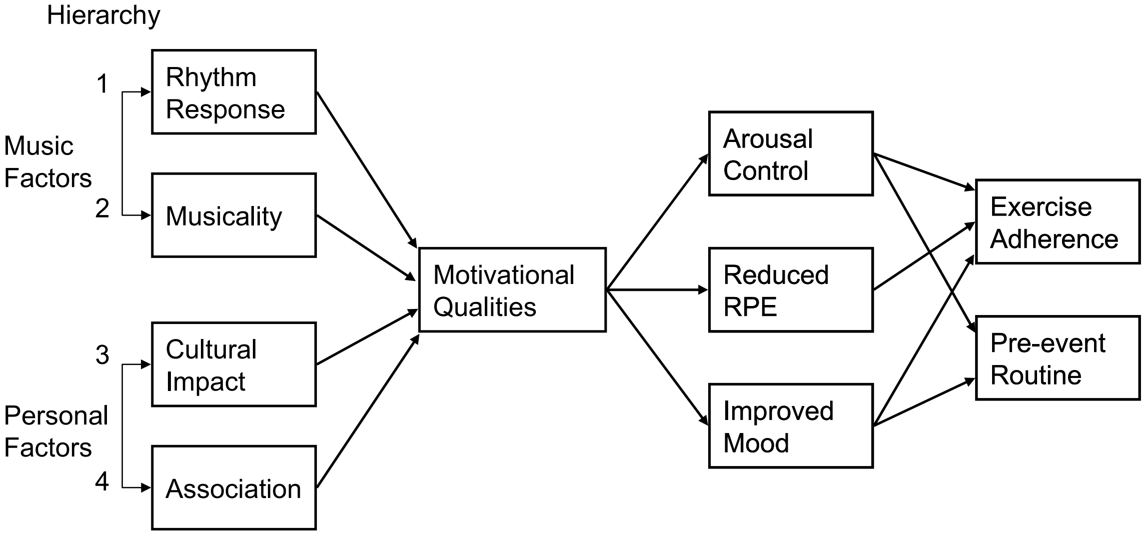

Figure 2.5. Karageorghis et al.'s (1999) revised conceptual framework for the prediction of responses to motivational asynchronous music in exercise and sport (adapted from Karageorghis et al., 1999).

The effects of music on physical performance have since been interpreted in terms of its motivational qualities, as measured by the BMRI (Karageorghis et al., 1999). Indeed, Elliot et al. (2003) designated music as *motivational* according to the BMRI, in their investigation of ergometer performance. Crust and Clough (2006) used the BMRI to enable selection of a suitable track for the motivational music condition, in their examination of the effects of music on an isometric weight-holding task. Crust and Clough highlighted the need to readdress the hierarchical arrangement of Karageorghis et al.'s (1999) factors contributing to music's ergogenic effects, drawing attention to the possible importance of personal meaning over rhythmic response in tasks of this nature; given the overwhelming emotional responses previously elicited by self-selected music (Rickard, 2004), this may be a fruitful avenue for investigation.

The BMRI (Karageorghis et al., 1999) was later modified to form the BMRI-2 (Karageorghis, Priest, Terry, Chatzisarantis, & Lane, 2006), a six-item measure specific to exercise environments. Karageorghis, Priest, et al. (2006) concluded that the BMRI-2 provides a valid and internally consistent tool for the selection of musical accompaniment for a physical training bout. The utility of the BMRI-2 has since been exploited by Simpson and Karageorghis (2006), who used the instrument to purposively select music to accompany 400 m sprint performance. However, if future research is to harness the utility of this instrument, consideration should be given to the fact that music's motivational qualities may be heavily influenced by a combination of personal and environmental factors (Priest, Karageorghis, & Sharp, 2004), and may not always be reflected in traditional measures of affective responding. This was evidenced in Tenenbaum et al.'s (2004) study, wherein participants reported that music did help in treadmill performance, despite no significant differences in perceived exertion.

2.4.3 *Work Output in Aerobic Activity*

Anshel and Marisi's (1978) oft-cited study indicated that ergometer cycling performance that is synchronised with accompanying musical tempo (i.e., synchronous music) is improved. However, Becker et al. (1994) found that the type of music makes no difference: what they termed *frenetic* (cf. Gaston's [1951] *stimulative* delineation) music exerted no effect on performance over and above that exhibited in a *mellow* (cf. *sedative*) music condition; both music conditions improved performance over a white noise control. However, this effect did not occur in a senior group (age ≥ 60 years); Becker et al. (1994) did not take into account age-related differences in preference. This might have increased the senior group's annoyance, for example. Becker, Chambliss, Marsh, and Montemayor (1995) subsequently sought to account for this observed difference in the seniors, and found that mellow music reduced walking distance, but there was no ergogenic effect associated with frenetic music.

In their examination of the effects of tempo on physical performance, Szabo, Small, and Leigh (1999) asked 24 participants to perform cycle ergometer exercise under each of five conditions: A no-music control, slow music, fast music, slow-to-fast music, and fast-to-slow music[2]. Participants started to cycle at 50 W, and the workload was progressively increased by 25 W per min until the participants felt that they could not sustain the exercise. Szabo et al. found that, despite no significant differences in heart rate across conditions, switching from slow to fast tempo resulted in significant differences in time to exhaustion, when contrasted with other conditions. Participants also expressed a preference for the fast music and slow-to-fast music conditions, which might have been due to the ability of these musical stimuli to distract from sensations of fatigue (cf. Boutcher & Trenske, 1990).

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[2] The tempo was changed in these last two conditions once the participant's heart rate had reached 70% of their heart rate reserve.

However, this may also suggest an innate preference for congruence between musical tempi and working heart rate (cf. Iwanaga, 1995a, 1995b; Karageorghis, Jones et al., 2006).

Elliott, Carr, and Savage (2003) examined the effects of motivational music (as determined by the BMRI (Karageorghis et al., 1999) on ergometer work output by 18 participants. Intensity of effort was established by subjective means. Specifically, all participants were required to cycle at a standardised RPE (Borg, 1971) of 13 for three 12-min trials under conditions of no-music, oudeterous music, and motivational music. All motivational music was standardised for tempo, cultural appropriateness, and familiarity (all selections had appeared in the British music charts within the preceding year, and all participants had expressed a liking for the idiom used, *dance music*). Participants also rated their affective response using Rejeski's (1985) 11-point Feeling Scale, at three-min intervals (3, 6, 9, and 12 min). Participants cycled significantly further in the motivational music condition than in the no-music condition, and displayed significantly higher levels of affect in both music conditions, when compared to the no-music control condition. Interestingly, in a subsequent study, Elliott, Carr, and Orme (2005) found that music classified as *oudeterous* according to the BMRI (Karageorghis et al., 1999) was as effective in increasing distance travelled in a submaximal cycling task as was music classified as motivating.

In an attempt to address perceived shortfalls in previous experimental investigations of the ergogenic effects of music – which had primarily utilised constant power tests to exhaustion as dependent variables – Atkinson et al. (2004) examined whether music improved initial, ultimate, and overall power during a 10 km cycling time trial. Sixteen participants performed two time trials on a Cybex cycle ergometer with and without *trance* music played at approximately 142 bpm and 87 dB. Each participant completed the BMRI (Karageorghis et al., 1999) after each music time trial. Mean time to complete the time trial was 1030 ± 79 s in the music condition compared to 1052 ± 77 s without music; this lies in contradiction to Schwartz, Fernhall, and Plowman's (1990) earlier findings. However, the largest music-induced increases in cycling speed and heart rate were observed in the first 3 km of the time trial. Participants rated the *tempo* and *rhythm* components (intrinsic factors) of the music as more motivating than the *harmony* and *melody* components (extrinsic factors), on the BMRI (Karageorghis et al., 1999). Atkinson et al. (2004) concluded that music may improve cycling time trial performance predominantly for the first few minutes of a 10 km time trial. Their findings suggest that music may serve a motivational function to a point at which the competing painful stimuli/sensations in the body attenuate the ergogenic effect, thereby rendering the music ineffectual. Both Elliott et al.'s (2003) and Atkinson et al.'s (2004) research yielded contradictory evidence to a much earlier study by Nelson (1963), who reported no differences in performance on a 90 s all-out ergometer cycle trial, when comparing *music* versus *no-music* conditions (the delivery of pure tones at varying frequencies and varied music intensity). None of Nelson's experimental manipulations yielded performance differences. However, participants reported feeling better when cycling to music with fast tempi played at high intensities. The absence of any significant main effect could be attributed to the all-out nature of the task, which necessitated complete focus on the task itself; any distracters were likely to have been ignored for the comparatively short duration of the test.

Mertesdorf (1994) found that ergometer exercise synchronised to music can reduce participants' boredom. Karageorghis and Terry (1997) were the first to explicitly bring the property of synchronicity as a potential mediator of music's effects in sport and exercise to researchers' attention, and this factor has been investigated subsequently (Simpson & Karageorghis, 2006). Karageorghis (2000) examined the differences in ergometer performance resulting from listening to both synchronous and asynchronous music, and found that performance was enhanced in both music conditions, relative to two control conditions (synchronising to a revolution meter or to a flashing metronome). Karageorghis noted that the mean differences in post hoc tests were slightly more pronounced for synchronous than asynchronous music, lending some support to the experimental hypothesis.

Researchers have shied away from using the treadmill to assess physical work performance, perhaps of the hazards of using this equipment to bring about exercise intensities approaching maximal capacity. However, Bharani, Sahu, and Mathew (2004) asked 20 healthy male volunteers to exercise until exhaustion on two occasions within a 24-75 hr period, once with self-selected music as accompaniment, once without music. When listening to music, participants exercised for over 17% longer, achieving higher mean peak heart rates as they did so (201 bpm vs. 195 bpm) and showed lower RPE at equivalent objective exercise intensities (6.5 vs. 7.6), when compared to exercising without music. This study lends further credence to the notion that self-selected music may be preferable to researcher-imposed selections if one is looking to maximise a specific emotional or behavioural response (Davis & Thaut, 1989; Pates, Karageorghis, Fryer, & Maynard, 2003; Rickard, 2004). However, examination of intrinsic sources of emotion (e.g., tempo) may preclude the use self-selected music in the present research programme, in order to effectively isolate these variables and their effects.

2.4.4 *Local Muscular Strength and Anaerobic Endurance Performance*

Kodzhaspirov, Zaitsev, and Kosarev (1986) used what they termed *functional music* to accompany elite weightlifters’ training sessions over a period of 2 years. All participants claimed that music improved their mood, while more than 89% of them noted (a) improved quality of sessions, (b) an increase in the volume of training, and (c) an increase in the intensity of training. However, Kodzhaspirov et al. (1986) did not assess performance objectively. There is some evidence that music may affect physical performance adversely. For example, Thaut, Schleiffers, and Davis (1991) looked at EMG activity in biceps and triceps in a simple gross motor task; co-contraction of the muscles was increased immediately prior to target movements in the presence of music; this increase in unwanted muscular tension would likely hamper the performance of a motor task.

Karageorghis et al. (1996) examined the effects of different types of music upon performance on a hand grip dynamometer, replicating the design of an earlier study by Pearce (1981). Participants were played music or white noise through headphones immediately prior to each trial. Significantly higher grip strength was evinced in the stimulative music condition, as compared to a sedative music condition and a white noise control condition. Pearce (1981) and Dorney et al. (1992) had previously found no such differences, however. Karageorghis et al. concluded that “a simple motoric task such as grip strength appears to provide an effective index of the ergogenic properties of music” (p. 1352). Crust and Clough (2006) recently used motivational music to accompany an isometric weight-holding exercise. They reported that participants endured the task for significantly longer in the presence of motivational music than in a rhythm or a no-music control condition. The authors suggested that the effects of motivational music may be mediated by personality to some degree. Specifically, participant’s scores for the *liveliness* sub-dimension of Cattell’s 16 Personality Factor questionnaire (Cattell, Cattell, & Cattell, 1993) were correlated with their response to music. Therefore, it may be worthwhile for future researchers to consider the overarching dimension of *extraversion*, the activation element of which has brainstem origins (Malmo, 1959).

2.4.5 *Physiological Parameters*

One of the earliest recorded studies into the physiological consequences of listening to music was conducted by Ellis and Brighouse (1952), who played three music selections to participants, which the researchers classified as *subdued jazz selection in the blues idiom*, *a soothing classical collection*, and *a vivid and dynamic classical selection*. Heart rate (assessed via ECG) and respiration rate (assessed via pneumograph) were measured at 1 min intervals during listening and for 5 min afterwards, once baselines for each had been established. All of the music conditions elicited statistically significant increases in respiration rate, but no such changes were manifested in heart rate. Ellis and Brighouse (1952) concluded that music could be used as a therapeutic agent, if one wanted to increase respiration rate. Given the relationships between exercise-related fatigue and cerebral oxygenation (Shibuya, Tanaka, Kuboyama, Murai, & Ogaki, 2004), and regular oxygenation and cognitive functioning (Kara, Pinar, Ugur, & Oguz, 2005), music listening may be a useful pre-performance strategy in sports where cognitive demands are high, and performance duration and intensity are long and high respectively, such as in tennis (Fernandez, Mendez-Villanueva, & Pluim, 2006).

Dorney et al. (1992) found contradictory results in their examination of the effects of music on the heart rate (HR) of participants who were preparing for two different tasks. In the first study, participants performed a dart-throwing task on three occasions; after listening to slow classical music, fast modern music, or no-music (control). HR was reduced in both music conditions relative to the control condition, but performance did not vary. In a second study, an imagery-plus-music group showed an increase in HR during preparation for a sit-up task when compared to an imagery-only group, but again there was no concomitant effect on performance. Karageorghis and Terry (1997) suggested that music can enhance the impact of imagery, and hence, may contribute to the efficacy of pre-performance strategies in eliciting facilitative emotional responses. This remains to be tested empirically.

The effects of music on HR are generally equivocal. For example, Lee (1989) reported no significant differences in HR during submaximal treadmill running between a Baroque music condition, an upbeat rock selection and a no-music control condition. Ferguson (1994) found little effect of sedative or stimulative music on HR and blood pressure

(BP) among students performing a cycle ergometer test. Boutcher and Trenske (1990) found that music had no effect on HR during cycle ergometer bouts at light, moderate, and heavy workloads. However, there is some evidence to suggest a relationship between exercise heart rate and preferred tempo (Iwanaga, 1995a; Karageorghis, Jones et al., 2006), which may be mediated by the autonomic nervous system (Iwanaga, 1995b); excitative music appears to decrease parasympathetic nervous system activation (Iwanaga, Kobayashi, & Kawasaki, 2005), lending support to earlier research (Iwanaga & Tsukamoto, 1997).

The sometimes contradictory results obtained for the effects of music on physiological variables may be explained, in part, by the possibility that an individual's interpretation of the music, rather than the musical characteristics per se, determines the psychophysiological response (Karageorghis & Terry, 1997). This could be determined, in part, by the situation in which one finds oneself: North and Hargreaves (1997a) noted that "…people who are in a state of unpleasantly high arousal (e.g. driving in busy traffic) will prefer quiet, relaxing music, whereas people who are in a state of pleasantly high arousal (e.g. exercising) will prefer loud, stimulating music" (p. 77).

Brownley, McMurray, and Hackney (1995) showed that music tempo can moderate levels of cortisol during graded treadmill exercise, indicating a stress-reducing effect of music listening. However, affective (self-report on a feeling scale) and skin temperature responses to musical accompaniment only appeared to benefit untrained runners. Yamamoto, Ohkuwa, Itoh, Kitoh, Terasawa, and Tsuda (2003) found that listening to fast music increased pre-exercise blood epinephrine levels, when compared to slow music, but this did not translate into superior performance on an all-out 45 s supramaximal cycle ergometer test. This autonomic component of the fight-flight response might have utility in other sporting situations, which require rapid reactive responding, but do not place maximal demands on an individual's physical capacities. One such example is the return of serve scenario in tennis.

2.4.6 *Cognitive and Attentional Performance*

Music has traditionally been used in order to facilitate teaching and performance of motor skills (Beisman, 1967; Chen, 1985; A. R. Ferguson, Carbonneau, & Chambliss, 1994; Jernberg, 1982), but relatively few studies have explicitly investigated the effects of music on cognitive performance. Smith and Morris (1976) examined the effects of stimulative music, sedative music, and no-music on the performance of 66 psychology students taking their first examination of a semester. Music conditions for the two treatment groups was selected from a selection of *classical*, *jazz and blues*, *country-bluegrass*, *easy listening*, *rock*, and *rock and roll* genres. Before and after each test session, participants completed a five item questionnaire designed to assess (a) worry about the test, (b) emotionality or physiological-affective arousal, (c) ability to concentrate, (d) expectancy of performance, and (e) like or dislike of the music. Stimulative music significantly increased both worry and emotionality while sedative music had no effect on anxiety relative to that of the control group. Performance on the multiple choice test was not affected by the music. Smith and Morris (1977) obtained similar results with a group of 60 students taking another test: stimulative music increased participants' worry scores, decreased ability to concentrate during the test, and decreased their performance expectations; the authors posited the future consideration of complex interactive cognitive processes when investigating the effects of music on test performance, rather than on the basis of physiological-affective processes alone. Other studies have shown no effect of relaxing music on anxiety scores during classroom test administration (Summers, Hoffman, Neff, Hanson, & Pierce, 1990).

Cockerton, Moore, and Norman (1997) investigated the effects of background music on cognitive test performance in 30 undergraduates. Performance was enhanced in the music condition insofar as participants answered more questions, and gave more correct answers. However, Furnham and Bradley (1997) and Furnham and Strbac (2002) caution that introverts may exhibit worse performance than extraverts in such situations, in line with the Eysenckian (1967) hypothesis of the inherent difference in optimum cortical arousal levels for introverts and extraverts.

Improvements in cognitive performance may be a result of enhanced mood. Schellenberg et al. (2007) demonstrated that Canadian undergraduates performed better on an IQ test after listening to an up-tempo Mozart composition, when compared to a slow piece by Albinoni. The effect was evident, however, only when the two pieces also induced reliable differences in arousal and mood. The authors therefore concluded that the difference was not due to Mozart's music per se. In a second study, Japanese 5 years olds drew for a longer time after singing or hearing familiar children's songs than after hearing Mozart or Albinoni, and their drawings were judged by adults to be more creative, energetic, and technically proficient. These findings are consistent with Isen's (1987) observations of the effects of positive mood on creative flexibility.

2.4.6.1 *Music as a Dissociation Strategy*

Morgan and colleagues (Morgan, 1978; Morgan & Pollock, 1977a, 1977b) used the terms *association* and *dissociation* to categorise cognitive strategies during distance running. Association refers to paying attention to bodily sensations (e.g., fatigue), while dissociation means paying attention to other non-performance-related stimuli such as the environment. A dissociative attentional focus has been shown to improve local muscular endurance performance (Gill & Strom, 1985); but Weinberg, Smith, Jackson, and Gould (1984) found no performance differences between groups of runners performing cognitive dissociation strategies and that of control groups. However, dissociation did result in greater persistence than association or control conditions. Gluch (1993) provided some evidence that athletes from a variety of individual and team sports use music to dissociate from their environment.

Heightened attention to symptoms of physical exertion can magnify the perception of that effort (Pennebaker & Lightner, 1980). Therefore, any strategy that draws attention away from physical sensations may reduce RPE (Borg, 1974, 1982, 1998) during physical performance. Johnson and Siegel (1987) found that music reduced perceptions of fatigue during participants' ergometer performance at 90% of $\dot{V}O_{2\ \max}$, although an active attentional manipulation (mental arithmetic) was more effective than music. Scott, Scott, Bedic and Dowd (1999) examined the effects of UK Top 40 pop music, a dissociative video condition, and an association tape on nine rowers' performance in an ergometer distance trial. Each rower covered a greater distance in the associative condition than in the other two. However, the music was not self-selected; disinterest in the music might have prompted associative strategies from the participants.

Association appears to be more beneficial during trained individuals' performance of tasks requiring extended effort (Morgan & Pollock, 1977a), whereas dissociation may be more effective for untrained individuals (Johnson & Siegel, 1987). However, dissociation in a sports performance preparation context might have very different implications; for example, enabling the performer to psychologically detach themselves from an otherwise stressful environment.

2.4.6.2 *Music and Vigilance Performance*

Vigilance tasks necessitate that the participant sustains attentiveness while waiting for an uncommon, unpredictable event, such as occurs when monitoring security cameras or a radar display. Experimental research on music effects on vigilance indicates that music has an ergogenic effect, but this is dependent on a number of characteristics of not only the listening situation, but also the listener. For example Geen, McCown, and Broyles (1985) asked 40 undergraduates previously classified as introverts or extraverts to perform a visual vigilance task, while listening to noise at either 65 or 85 dB. At 65 dB, introverts demonstrated improved detection rate across trials, while noise delivered at 85 dB degraded detection rate; the converse occurred for extraverts. Geen et al. interpreted their results in terms of personality-mediated arousal.

Discontinuous unpredictable music played as background stimulation is more likely to lead to improved vigilance performance. This phenomenon was reported by Davenport (1974), who asked 48 students to participate in a vigilance task in which they were required to view an oscilloscope screen for a total of 160 min, and to press a response key upon detection of a deviation in the amplitude of an otherwise static sine wave pattern. During this task, participants heard a background schedule of four different types of musical accompaniment, each lasting 40 min: Fixed interval music, with 20 s silence periods interspersed in between 20 s music periods; continuous music; variable interval music, in which the silence periods varied from 15 to 25 s in length; and random interval music, wherein music and silence periods were arranged in a completely random order. All participants attained a higher percentage of detections in the variable interval and random interval music conditions, when compared to continuous music and fixed interval music conditions. Davenport interpreted his results in terms of the arousal theory of vigilance. Specifically, they indicated that reduced predictability in the background environment may enhance vigilance performance, and that this may be altered simply by continually changing the music stimulus.

There is evidence that extrinsic sources of emotions in music may be more important mediators of the effect of music on vigilance performance than intrinsic factors. Fontaine and Schwalm (1979) described the potential impact of what they termed the *psychological variable* of familiarity on physiological and performance measures in a vigilance task. They asked 35 undergraduates to perform a vigilance task under one of five listening conditions: *Familiar rock*, *familiar easy-listening*, *unfamiliar rock*, *unfamiliar easy-listening*, and a no-music control condition. Familiar music significantly increased participants' heart rate and the percentage of detections; and it also attenuated the vigilance decrement (i.e., a drop in vigilance performance occurring as a function of a number of task demand characteristics). It is notable that music genre had no significant effect on either heart rate or performance, but the authors did not address this finding. This anomaly somewhat reflects the fact that the role of acculturation in development of music preferences has only been more recently investigated (e.g., Hargreaves & Castell, 1986).

North and Hargreaves (1999) reported that manipulation of the physical properties may be sufficient to alter the effects of music on performance in an ecologically valid task in which visual vigilance is required. Participants completed five laps of a computer motor racing game whilst listening to *high arousal* or *low arousal* music in either the presence or absence of a backward-counting task. In order to create the two music conditions, the same excerpt of pre-recorded music was manipulated so that the *low arousal* version was played at a tempo of 80 bpm, while the *high arousal* version was played at 140 bpm; intensities for each were 60 dB and 80 dB respectively. Both manipulations affected performance on the game, with arousing music and backward-counting leading to slower lap times than relatively unarousing music and the absence of the backward-counting task. Counting backwards also reduced participants' liking for the music more than in its absence. The results also indicated that liking for the music was positively related to task performance, and in conjunction these findings seem to suggest a direct link between music and the listening context. North and Hargreaves (1999) suggested that the music and the task competed for a limited processing resource; they interpreted their results with reference to Konecni's (1982) assertion that musical preference is subject to an interaction between musically-evoked arousal and cognitive demands resulting from the concurrent tasks; musically-induced arousal reduces the amount of attentional space available for cognitive task performance (Broadbent, 1971;

Easterbrook, 1959). This assertion posits that less arousing music should be more liked than arousing music when played during performance on a complex task, and that liking for arousing music will increase as more cognitive processing space is freed up; this was partly borne out in Konecni and Sargent-Pollock's (1976) earlier research.

2.4.6.3 *Reaction Time*

Music can improve motor reaction time (Zakharova & Ivaschenko, 1984); an effect which extends to teenage populations (Bassagaoglu, Kalkan, & Sari, 2004). Evidence suggests that reaction time is significantly negatively correlated with amplitude of cortical activity in areas of visual cortex and sensorimotor cortex, as revealed by fMRI (Mohamed, Yousem, Tekes, Browner, & Calhoun, 2004). Pre-stimulus EEG activity has also correlated with performance on an acoustic choice reaction-time task (Winterer, Adams, W, & Knutson, 2002). Despite this, the relation between music listening and reaction time performance has been confined to examinations of contemporary presentations of the two stimuli. Music may exert its effects through enhanced visual attention processes (Amezcua, Guevara, & Ramos-Loyo, 2005), and *comfortable* music intensity may be conducive to superior reaction time performance (M. L. Turner, Fernandez, & Nelson, 1996), although this may be confined to real-world paradigms in which cognitive load is high, such as driving. Beh and Hirst (1999) demonstrated that both low- and high-intensity music can improve responding to signals within central vision while driving, but high intensity music reduced peripheral responding – a significant risk factor in such settings.

2.4.6.4 *The Mozart Effect*

The Mozart effect refers to the specific claim that listening to Mozart's Sonata for Two Pianos in D Major (K.448) can improve the performance in spatiotemporal tasks, first put forward by Rauscher, Shaw, and Ky (1993). Rauscher et al. (1993) played Mozart's composition to students for 10 min prior to testing their spatial reasoning skills, as assessed by the Stanford-Binet intelligence scale (Thorndike, Hagen, & Sattler, 1986); performance was contrasted with that after 10 min of listening to relaxation instructions, or after a period of silence. Participants were significantly more intelligent after listening to the music, than after relaxation and silence conditions. The authors ruled out the role of arousal in eliciting these differences, instead suggesting a role for higher musical complexity in yielding such improvements. Subsequent research has supported Rauscher et al.'s (1993) findings (e.g., Rideout & Taylor, 1997); this includes electrophysiological data (S. Martens, Munneke, Smid, & Johnson, 2006); and this effect has been generalised to more recent musical genres (Rideout, Dougherty, & Wernert, 1998).

In reviewing the studies which have failed to replicate the Mozart effect, Rauscher and Shaw (1998) concluded that they can be explained in terms of the various dependent measures used; some studies employed entirely different measures of ability. In light of this, Rauscher and Shaw subsequently curbed the original claim, to state that listening to the sonata improves people's subsequent ability to mentally transform images. However, Thompson, Schellenberg, and Husain (2001) contended that the Mozart effect is simply a function of increased arousal and heightened mood. They asked two groups of students to perform a paper folding and cutting task derived from the Stanford-Binet intelligence test (Thorndike et al., 1986), either after a period of silence, or after listening to a piece of classical music (Mozart or Albinoni). Measures from the POMS (McNair et al., 1971) and a bespoke global mood-arousal rating were also taken. Performance on the task was significantly improved after listening to the Mozart piece, when contrasted with silence; the sadder and slower Albinoni piece did not elicit such differences. Scores on the concomitant measures suggested that arousal was an important mediatory factor in the performance differences seen, as per Thompson et al.'s hypothesis. Given the apparent differences in the makeup of the two pieces, it seems likely that the tempo and affective tone of the music heard could also play a pivotal role.

Ho, Mason, and Spence (2007) examined whether the Mozart effect would influence the *temporal* component of attention using a visual attentional blink task; the attentional blink refers to the inability to detect the second of two rapidly consecutively presented stimuli when the onset delay is 400 ms or less (Raymond, Shapiro, & Arnell, 1992). Participants had to identify two target digits (in their correct order of presentation) presented amongst a stream of distracter letters under three conditions: While listening to the Mozart sonata played normally, while listening to the same Mozart sonata played in reverse (this retained many acoustical qualities of the music, while theoretically reducing the aesthetic response associated with the normal version), and while in silence. Results showed that the participants were able to detect the second target (T2) significantly more accurately (given the correct detection of the first target, T1) in the attentional blink stream when the Mozart sonata was played normally than in either of the other two conditions. According to Ho et al., this was the first investigation to examine the temporal component of the AB phenomenon; neurophysiological investigation may elucidate the underpinning neural substrates.

2.4.7 *Music Listening Prior to Performance*

Adequate preparation for sport performance is seen as an essential component of effective performance (S. J. Bull, Shambrook, James, & Brooks, 2005; Eklund, 1996), but the use of music as a pre-competitive strategy has received scant attention in the literature, with the exception of a study by Gluch (1993). He interviewed four female and two male US college Division 1 athletes who stated that they used music as part of their performance preparation routine. Having established individual interview quotes as the basic unit of analysis, Gluch used inductive analysis, a process which facilitates the identification of themes and categories in the data (Scanlan, Stein, & Ravizza, 1989). However, Gluch misguidedly assumed that, having identified his sample, it was sufficient to analyse the data before reaching what he termed *saturation*; this is a concept commonly used in the literature to refer to a point where no new information is emerging (Biddle, Markland, Gilbourne, Chatzisarantis, & Sparkes, 2001; Fossey, Harvey, McDermott, & Davidson, 2002; Seale, 1999), and is commonly achieved through purposive sampling (Silverman, 2004). Gluch's sample appeared to be one of convenience only. He grouped the data into five separate categories: *Self-regulation*, *feelings of well-being*, *mental preparation*, *memories*, and *confidence*, although he did not explicitly identify how these were operationalised (e.g., antecedents, consequences, etc.).

2.4.7.1 *Manipulation of Mood*

Music listening appears to be a popular strategy for self-regulation of mood, especially in younger people (R. E. Thayer, Newman, & McClain, 1994). Hewston, Lane, Karageorghis, and Nevill (2004) investigated the efficacy of music as a strategy to regulate pre-competition mood, using the Brunel Mood Scale (BRUMS; Terry, Lane, Lane, & Keohane, 1999) to assess mood two hours prior to competition, immediately prior to competition and immediately afterwards. There were significant increases in calmness, happiness, and vigour subsequent to music listening, and significant reductions in depression and tension, when compared to no-music control conditions. However, Hewston et al. (2004) did not report any effects on performance, a dependent variable continually omitted from studies of the effects of music on variables related to sports performance.

2.4.7.2 *Flow*

Flow (Csikszentmihalyi, 1990) is a state characterized by nine components, which are collectively necessary and sufficient for flow to occur: challenge-skills balance, action-awareness merging, clear goals, unambiguous feedback, concentration on the task at hand, sense of control, loss of self-consciousness, transformation of time, and autotelic experience

(Csikszentmihalyi, 1990). Flow has been studied extensively in sport (Jackson, 1992, 1995a, 1996; Jackson & Csikszentmihalyi, 1999; Jackson & Eklund, 2002; Jackson, Kimiecik, Ford, & Marsh, 1998; Jackson & Marsh, 1996; Stein, Kimiecik, Daniels, & Jackson, 1995).

Interventions comprising self-selected music and imagery have been shown to enhance athletic performance, by triggering emotional responses associated with flow. Pates, Karageorghis et al. (2003) employed an idiographic single-subject multiple baselines across-subjects design to investigate the psychological and performance impact of listening to self-selected asynchronous music prior to a netball shooting task. Three netballers completed each of 11 performance trials comprising 12 shots from lines demarcated at three shooting positions. The Flow State Scale (FSS; Jackson & Marsh, 1996) and a practical assessment questionnaire adapted from Kazdin (1992) and Kendall, Hrycaiko, Martin, and Kendall (1990) were used to assess the participants' flow state and internal experience after each trial. Once baseline shooting performance had been established, an explanation of flow state, as described by Jackson and Marsh (1996), was given to each participant, and they were requested to mentally recreate the thoughts and feelings they associate with flow. Participants then selected music from their own personal selection which they deemed most likely to induce the flow state. After listening to this selection, the intervention shooting phase was undertaken. All participants exhibited improved flow scores and shooting performance post-intervention. However, it is not possible from viewing these results to differentiate between residual emotional effects from pre-performance music listening and the ergogenic effects of listening to music during performance.

2.5 The Sport of Tennis

Competitive tennis is globally played under International Tennis Federation (ITF) regulations; and the ITF Women's Circuit, for example, offers more than 250 international tournaments per year (International Tennis Federation, 1999). The ITF Rules of Tennis

(International Tennis Federation, 1999) stipulate that a singles match in one of these tournaments typically comprises the best of three sets (men's Grand Slam tournaments are played to the best of five sets), in each of which the victorious player must win by a margin of two games, having won six or more games in total. The first two sets are settled by a *tie break* if tied at six games per player; the tie break is played to a minimum of seven points for the winning player, and a two point differential must determine the eventual winner. The third (final) set, if reached, must be won by two clear games only; no tie break is played. Twenty seconds of rest are allowed between points in a game, 90 seconds are allowed between changeover periods (interspersed every two games, and a time during which players can sit down), and 120 s are allowed between sets.

2.5.1 The *Physical Demands of Tennis*

Fernandez et al. (2006) conducted a review of studies of the physical demands of tennis, spanning a 33 years period. The mean physiological responses to playing tennis were reportedly moderate, with mean exercise intensities of less than 60-70% of maximum oxygen uptake ($\dot{V}O_{2\ \mathrm{max}}$) (Christmass, Richmond, Cable, Arthur, & Hartmann, 1998; König, Hounker, & Schmid, 2000) and mean maximum heart rates of 60-80% of absolute maximum (Ferrauti, Weber, & Wright, 2003). But Fernandez et al. (2006) acknowledged that the intermittent nature of the sport rendered these values difficult to interpret. Indeed, mean heart rates varied from 143 bpm (Seliger, Ejem, & Pauer, 1973) to 181 bpm (Girard & Millet, 2004). Mean rally times were typically from 4.0 s (B. C. Elliott, Dawson, & Pyke, 1985) to 10.2 s (Christmass et al., 1998), corresponding to work-rest ratios of 1:3.1 and 1:1.7 respectively.

2.5.2 The *Psychological Demands of Tennis*

The impact of psychological skills usage on tennis performance has received some attention in the applied sport psychology literature (e.g., S. J. Bull, 1990; Daw & Burton, 1994; Mamassis & Doganis, 2004; Rees & Hardy, 2004; Sheldon & Eccles, 2005). As well as the physical demands of the sport, tennis players are continually faced with the need to assess, reassess, and manipulate their *zone of emotional functioning* (cf. Hanin, 1995) – either consciously or unconsciously; different stages of a match arguably necessitate different emotional profiles . Attempts to do this are made all the more challenging by oftentimes lengthy matches, together with frequent changeovers affording 90 s of introspection; introspection which can sometimes lead to choking (Baumeister, 1984) and shifts in psychological momentum (Iso Ahola & Mobily, 1980). One notable illustration of the occurrence of these phenomena at the very highest level is that of Guillermo Coria’s relinquishment of a 6-0, 5-0 lead over unseeded compatriot Gaston Gaudio in the final of the 2004 French Open (Wertheim & Bechtel, 2004). But in contrast to the potentially deleterious consequences, changeover periods also present the opportunity to positively manipulate psychophysiological states; and music listening has been shown to achieve this end (Copeland & Franks, 1991; D. Elliott et al., 2003). Nonetheless, prior research into affective experience in sport has primarily focused on pre-competitive phenomena, especially in the lead-up to competition (e.g., Hanton, Thomas et al., 2004).

Covassin and Pero (2004) examined the relationship between pre-competitive self-confidence, anxiety and mood states and performance in a group of 24 collegiate tennis players, using the Competitive State Anxiety Inventory-2 (CSAI-2, R. Martens et al., 1990) and the POMS (McNair et al., 1971). Successful players displayed lower cognitive anxiety, lower somatic anxiety, and higher self-confidence. Their scores on the POMS also exhibited an *iceberg profile* (Morgan, 1980), whilst those for losing players did not. Losers also had higher anger and vigour scores in comparison to college norms. However, measurements on both psychometric instruments were obtained 30 min prior to competition, a time in which many tennis players engage in a warm-up *hit*, which could have a considerable bearing on subsequent anxiety, confidence, and mood ratings – and, by extension, performance. The routine of completing the questionnaires might also have blighted the results, but the authors did not ascertain participants' perception of the inconvenience of spending 10-15 min completing the inventories.

Meyers and Sterling (1994) assessed the mood states and psychological skills usage of 45 world-ranked female tennis players. They employed the POMS (McNair et al., 1971) and a revised version of the Psychological Skills Inventory for Sport (PSIS, Mahoney, Gabriel, & Perkins, 1987). Players were divided into three groupings: Top-ranked, middle-ranked, and bottom-ranked. Meyers and Sterling found no differences between the three groups for the POMS subscales or for total mood disturbance. However, inventories were administered on non-competitive days, and did not relate to competition. This is a distinct weakness in the use of a psychometric instrument whose traditional use in sport has been to identify "right now" mood states predictive of successful athletic performance (LeUnes & Burger, 1998). There were also no significant differences in PSIS subscales, but the authors noted a non-significant trend towards increased confidence in higher ranked players, which is perhaps unsurprising, given the widely accepted link between self-efficacy and performance across a number of domains, including tennis (Bandura, 1997; Barling & Abel, 1983; McPherson & McCormick, 2006; Valentijn et al., 2006; Weinberg & Jackson, 1990).

Despite the ebb and flow of a typical tennis match, two key points at which psychological intervention can be highly effective are during the service and return of service; largely because the former is a *closed-type* skill and the latter is a *reactive skill* wherein variability of conditions is reduced in comparison to that encountered in open play. Video modelling has been used to develop both the service (Emmen, Wesseling, Bootsma, Whiting, & Van Wieringen, 1985) and return of service (Farrow, Chivers, Hardingham, & Sachse, 1998). Farrow and Abernethy (2002) used a progressive temporal occlusion paradigm to examine tennis players' ability to predict the direction of an opponent's service in an on-court setting. Participants responded either through hitting a return stroke or making a verbal prediction of stroke direction. An implicit learning group, whose training required them to predict serve speed direction while viewing temporally occluded footage, significantly improved their prediction accuracy after the training intervention, an effect which dissipated after a subsequent 32-day interval in which no training occurred. Participants in the explicit learning group, who were instructed in potentially informative pre-service kinematics, displayed no improvements. Using a similar temporal occlusion paradigm to examine expert-novice differences in the ability to predict service direction, Goulet, Fleury, and Bard (1989) discovered that experts not only made more correct responses, but were also able to identify directionality at earlier (preparatory) stages of the service motion.

The tennis environment is acknowledged as being potentially highly stressful, but can be mediated to a high degree by appropriate social support (Rees & Hardy, 2004). Sources of stress in tennis include negative comments from coaches or relatives, cheating by opponents (Puente-Díaz & Anshel, 2005); and the pressure of self and others' expectations, which can lead to antisocial behaviour such as racket breaking, self-directed physical and/or verbal abuse, and other-directed verbal abuse (Hanegby & Tenenbaum, 2001).

2.6 Methodological Considerations

2.6.1 *Selection of Appropriate Music Stimuli*

Karageorghis and Terry (1997) echoed Lucaccini and Kreit's (1972) earlier sentiment in their later review, by highlighting the onerous task facing researchers who wish to investigate the psychophysical effects of music listening in sport and exercise contexts: The list of extrinsic factors that can potentially contribute to emotional responses to music, for example, is theoretically limitless (cf. Sloboda & Juslin, 2001).

Harrer and Harrer (1977) suggested that, to elicit intended emotional responses to music in participants, one should give consideration to participants' self-selection of music. This sentiment was later repeated by Karageorghis et al. (1996), who suggested that the potential variability of preferences within even a culturally homogenous sample may be large; and by Karageorghis and Terry (1997), who criticised research in the area for failure to specify musical selections and the way in which they were used. The BMRI (Karageorghis et al., 1999) went some way towards the standardisation of musical selection. This seems especially important when considering the evidence to support powerful emotional responses to self-selected music. The BMRI-2 (Karageorghis, Priest et al., 2006) has retained the structural integrity of the BMRI, but has rendered selection of motivational music more straightforward and expeditious, due to its shorter length. Karageorghis, Priest, et al. delineated criteria for exercise leaders' selection of motivational music. In short, that it may be prudent to select music with potentially facilitative extra-musical associations (related and unrelated to sport or exercise), with a tempo that matches exercise heart rate, and of a genre that matches the demographics of the exercisers as closely as possible.

Rickard (2004) asked participants to select music they deemed to be *emotionally powerful* to examine the physiological responses to such music when compared to those elicited by a piece of music that was arousing for non-emotive reasons. When considering emotional responses to music, the extrinsic sources of emotion (Sloboda & Juslin, 2001) may be very important determinants of those responses. Indeed, self-selected music has been shown to promote the likelihood of *flow* (Csikszentmihalyi, 1990) occurring prior to execution of sport performance (Pates et al., 2003), and can have dramatic effects on subjective and physiological indices of anxiety during invasive medical operations (Palakanis et al., 1994); Thaut and Davis (1993) found contradictory evidence. Despite the potentially powerful effects of self-selected music, the more typical approach has been to use researcher-imposed musical selections. This, however, allows greater controllability on the part of the researcher; individualised responses to music can easily be captured using, for example, the BMRI (Karageorghis et al., 1999) or measures based on the circumplex model (North & Hargreaves, 1997b).

2.6.2 *Health and Safety Considerations*

2.6.2.1 *Sound intensity*

Exposure to loud music can cause temporary hearing loss, including during physical activity (Alessio & Hutchinson, 1991). The Health and Safety Commission (HSC) is responsible for health and safety regulation in the United Kingdom, and the Health and Safety Executive (HSE) and local government are the enforcing authorities who work in support of the Commission. The Control of Noise at Work Regulations (2005) came into force in the United Kingdom on 6 April 2006, to ensure that workers' hearing is protected from excessive noise at their place of work, which could cause them to lose their hearing and/or to suffer from tinnitus (permanent ringing in the ears). The level at which employers must provide hearing protection and hearing protection zones is 85 dB (daily or weekly average exposure) and the level at which employers must assess the risk to workers' health and provide them with information and training is 80 dB. There is also an exposure limit value of 87 dB, taking account of any reduction in exposure provided by hearing protection, above which workers must not be exposed. The Control of Noise at Work Regulations have implications for the current research programme, wherein participants were required to listen to music for extended periods of time at moderately high levels. This programme will take into consideration that young adults will tend to underestimate the magnitude of musical intensity when listening to their preferred music (Fucci, Harris, Petrosino, & Banks, 1993; Fucci, Petrosino, Banks, & Zaums, 1996).

2.6.2.2 *Research Ethics Committee approval*

Prior to commencement of data collection, approval for the entire research programme was sought from Brunel University's School of Education Research Ethics Committee. A copy of the approval letter from the Chair of the committee is in Appendix U.

2.6.3 *Mixed-Methods Research: Methodological Triangulation*

Miles and Huberman (1994) posited that the qualitative-quantitative argument is essentially unproductive, observing as follows:

> …the careful measurement, generalizable samples, experimental control, and statistical tools of good quantitative studies are precious assets. When they are combined with the up-close, deep, credible understanding of complex real-world contexts that characterize good qualitative studies, we have a very powerful mix. (p. 41)

Hammersley (1996) advocated that qualitative and quantitative research methods can be used together within the same research programme, saying that there is no contradiction in the objectives and characteristics of constructivist and positivist research; the modes of inquiry are simply different, and reflect what he termed *methodological eclecticism*. Parrott and Hertel (1999) suggested that increased systematic combination of multiple methods in both laboratory and in vivo settings would represent a significant advance in cognition and emotion research, remarking that such advances are necessary to continue the progress in understanding the causes and consequences of emotion from a cognitive perspective. Therefore, a research programme that possesses both inter- and intra-study methodological diversity is likely to yield meaningful and useful data for the further study of emotional responses to music listening in sport.

CHAPTER 3: A GROUNDED THEORY OF YOUNG TENNIS PLAYERS' USE OF MUSIC TO MANIPULATE EMOTIONAL STATE

3.1 Introduction

Music listening as a pre-performance strategy in sport has received limited attention in sport psychology research (e.g., Gluch, 1993) despite evidence for the capacity of music to elicit strong emotions (Gabrielsson, 2001), and for the apparent prevalence of music listening as a mood-regulation strategy in adolescents (Saarikallio & Erkkilä, 2007). This is possibly due to the idiosyncratic nature of musical preferences and responses to music, which limit the generalizability of findings. However, the idiosyncratic nature of emotional responses to music provides a potential avenue for manipulating athletes' pre-competitive emotions.

Regular changeover periods offer tennis players 90 s of introspection which may lead to sharp degradation in performance when under pressure (*choking*; Baumeister, 1984). However, changeovers also afford players an opportunity to *positively* influence their emotional state, and listening to music can achieve this end (Scherer, 2004). For example, R.E. Thayer et al. (1994) found that listening to music was rated as a successful behavioural strategy for self-regulation of mood; in particular it was deemed an effective strategy for increasing energy, reducing tension, and changing a bad mood – most notably for a younger subsample of their participants. Further, Gabrielsson (2001) reported that positive emotions (e.g., elation, happiness, rapture, and thrill) were dominant in respondents' experiences with music, and that such experiences were influenced by a combination of musical, personal, and situational factors.

Although listening to personal music is not permitted during play in some major events such as The Wimbledon Championships (Lawn Tennis Association [LTA], personal communication, October 10, 2005), the International Tennis Federation Junior Circuit Regulations (2007) make no such stipulations at the time of writing. Junior tennis players may be able to listen to music *prior* to the start or recommencement of play, and research indicates that music listening may exert an ergogenic effect upon a number of facets of physical performance (see Karageorghis & Terry, 1997).

Evidence suggests that listening to sedative/relaxing music may reduce the rate of perceived exertion during submaximal exercise (Copeland & Franks, 1991), and listening to music classified as *lively* can enhance affective states at both medium and high levels of work intensity (Boutcher & Trenske, 1990); this may operate through an attentional shift from internal (somatic) cues to external (music) cues (Szabo et al., 1999). Other evidence indicates that at high exercise intensities, music has no impact on affective responses to exercise: Tenenbaum et al. (2004) investigated the effect of three classifications of music (rock, dance, and inspirational) on performance, perceptions of fatigue and discomfort during treadmill running at 90% $\dot{V}O_{2max}$, and found no differences between each music condition and a no-music control condition; participants did, however, report a beneficial (dissociative) shift in attentional focus in response to music.

Music mediates not only affective responses, but also other facets of performance: Synchronization of submaximal exercise with musical accompaniment can increase work output (Atkinson et al., 2004), and synchronization of motivational music with predominantly anaerobic tasks can also improve performance (Simpson & Karageorghis, 2006). Karageorghis et al. (1996) examined the effect of stimulative music (tempo 134 bpm) relative to sedative music (tempo 90 bpm) and white noise, when played immediately prior to execution of a grip strength task. They found that grip strength was greater after listening to stimulative music; the extent of this effect has since been shown to be mediated by aspects of personality (Crust & Clough, 2006). Neurophysiological indices of performance also show some relationship with music properties: Karageorghis, Jones et al. (2006) showed that heart rate during exercise exhibits a moderate correlation with preferred music tempo, corroborating Iwanaga’s (1995) earlier research; and latency of neural responses to visual stimuli are reduced when listening to fast tempo music – reflecting a more rapid evaluation of the stimulus (Amezcua et al., 2005).

To address the consistently problematic issue of appropriate music selection in sport and exercise contexts, Karageorghis et al. (1999) developed the Brunel Music Rating Inventory (BMRI). This measure stemmed from a conceptual framework in which four factors are deemed to contribute to the motivational qualities of music: *Rhythm response*, *musicality* (both music factors), *cultural impact*, and *association* (both personal factors). The BMRI was later redesigned to form the BMRI-2 (Karageorghis, Priest et al., 2006) to gauge the motivational qualities of music in exercise environments. However, due to the complex nature of precompetitive emotions (Hanin, 2000), assessing the motivational impact of a track may not capture the efficacy of music listening as a pre-performance strategy. Also, the study of music in sport has focused primarily on the potential role of music as an ergogenic aid when used to accompany performance, despite the ability of music to elicit enduring autonomic and endocrine changes (Scherer, 2004), which may affect subsequent performance.

Emotions are an integral part of human existence, mediating almost every facet of human behavior. They are characterized by physiological (Ekman et al., 1983), neurophysiological (Damasio, 2000), facial expression (Russell & Bullock, 1985), behavioural (Frijda, 1986), and affective (Russell, 1980) components. Damasio (2000) highlighted the regulatory role of emotions, stating that they lead "…in one way or another to the creation of circumstances advantageous to the organism…their role is to assist the organism in maintaining life" (p. 51). Although contemporary sport is not a matter of life and death, it has evolved to become a substitute for such situations. Appropriate emotional patterns are necessary for sporting success, and there is evidence that music can elicit potentially performance-facilitating neurophysiological (Menon & Levitin, 2005) and affective (Gabrielsson, 2001) states.

R. E. Thayer, Newman, and McClain (1994) found that listening to music was rated as a successful behavioural strategy for self-regulation of mood. In particular it was deemed an effective strategy for increasing energy, reducing tension, and changing a bad mood, most notably for a younger subsample of their participants. This finding is comparable to that of Saarikallio and Erkkilä (2007), whose adolescent participants used music predominantly to strengthen positive feelings, to move away from negative feelings, and to increase emotional intensity. Saarikallio and Erkkilä developed a model of adolescents' mood regulation by music, depicted in Figure 3.1. As per Gabrielsson's (2001) and Scherer and Zentner's (2001) suggestions, the model depicts an interaction between contextual (situational), personal (listener), and music factors. It can be seen that a primary function of music listening in this group of participants was the promotion of emotional self-regulation, incorporating mood.

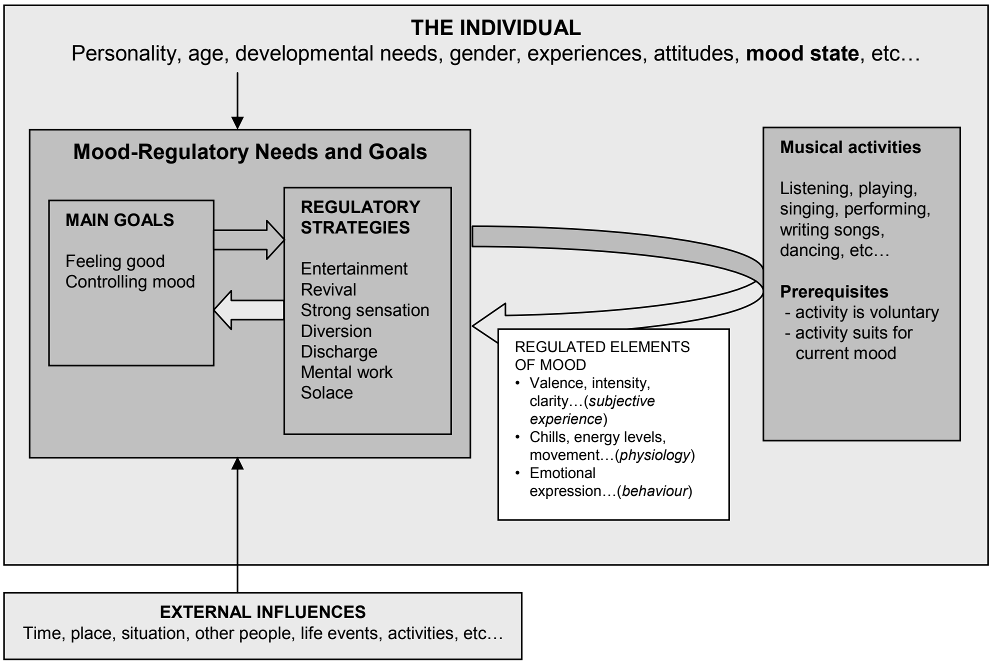

Figure 3.1. A model of adolescents' emotion self-regulation by music (adapted from Saarikallio & Erkkilä, 2007).

Two elements of mood identified by Saarikallio and Erkkilä as important to their participants' use of music as a mood regulation strategy were the intensity and valence of the affective experience; two dimensions which collectively delineate Russell's (1980) affective circumplex model.

Despite Russell et al.'s (1989) successful modification of the circumplex model to produce the single-item Affect Grid, North and Hargreaves (1997) investigated musically-induced emotions with a two separate measures for each of the two circumplex model continua, and concluded that ratings of the emotions expressed by a musical excerpt can be reliably predicted by (a) the extent to which listeners like the piece, and (b) the extent to which they are aroused by it, an assertion which has since received empirical support (Ritossa & Rickard, 2004). Arousal is a concept central to many theories and models of emotion (e.g., J. F. Thayer & Faith, 2001), and arousal regulation strategies have been posited as important moderators of emotional control in sport (Jones, 2003). Liking for musical stimuli is closely related to the pleasure derived (Ritossa & Rickard, 2004); and happiness – a key component of the feeling of pleasure – is attracting attention as an important primary emotion in both musicology (Webster & Weir, 2005) and sport emotion research (Jones et al., 2005). Therefore, measures based on the circumplex model present potent and time-efficient means for measuring emotional responses to music listening in sport.

3.1.1 *Methodological Considerations*

3.1.1.1 *Qualitative research*. Qualitative research, a methodology which has been gaining in popularity in sport psychology research for over a decade (Culver, Gilbert, & Trudel, 2003; Jackson, 1995b; Strean, 1998), does not typically require specific hypotheses at the outset; they are induced during the early stages of research. Hypotheses emanating from qualitative research should be assessed by their validity or truth (Silverman, 2004). Sport researchers who have explored different qualitative approaches have stressed the need to use criteria which more closely reflect the nature of the research process which has been undertaken, when seeking to legitimise findings (Faulkner & Sparkes, 1999; Gilbourne, 1998). Indeed, Hardy, Jones, and Gould (1996) had earlier argued that the positivist concept of internal validity corresponds to the qualitative criteria of credibility, external validity to transferability, reliability to dependability and objectivity to confirmability.

While this juxtaposition of these concepts serves to highlight the sometimes nebulous and often subjective nature of all research, irrespective of the researcher’s paradigmatic proclivities, it also reflects the fact that the investigator is the instrument (L. Richardson, 1994) because he or she forms and asks the interview questions and/or decides what to observe and record. Therefore it behoves the researcher to demonstrate his or her ability to conduct qualitative research, which is difficult when considering that there are no objective criteria against which readers can confirm “quality” (McKenna & Mutrie, 2003); however, Rew, Bechtel, and Sapp (1993) listed appropriateness, authenticity, credibility, intuitiveness, receptivity, reciprocity and sensitivity as being important attributes for any qualitative researcher; these sentiments have been echoed by qualitative researchers in sport (Biddle et al., 2001; Culver et al., 2003; Sparkes, 1998).

Silverman (2004) proffered four guidelines for conducting effective qualitative research: (a) keep it simple, (b) take advantage of what qualitative data can offer, (c) avoid drowning in data, and (d) avoid journalistic questions and answers. He also provides four solutions to enable the researcher to generalise from qualitative data: Combining qualitative and quantitative measures, time- and resource-guided purposive sampling, theoretical sampling using a model which assumes that generalizability is present in any case, and discovery-focused techniques which aim to establish patterns and connections among elements of data (p. 136). The depth of information afforded by qualitative research should also deter researchers from seeking to obtain high sample sizes (Sandelowski, 1995), which may (a) reduce the data quality and (b) lead to data management problems, according to Kvale (1996). Indeed, in-depth involvement is considered a greater priority than widespread sampling (McKenna & Mutrie, 2003).

3.1.1.2 *Grounded theory*. Grounded theory was conceived by Glaser and Strauss (1967), who wished to examine individual cases in order to generalise to wider populations. In grounded theorising, the theory is developed from discovered data, in contrast to more traditional approaches to theorising. The researcher does not begin a project with a preconceived theory in mind – unless his or her purpose is to elaborate and extend existing theory (Strauss & Corbin, 1998); and analysis need not be entirely inductive (Henwood & Pidgeon, 2003).

Dey (2003) offered a word of caution to both advocates and critics of grounded theory, stating that "…there is no such thing as 'grounded theory' if we mean by that a single, unified methodology, tightly defined and clearly specified. Instead, we have different interpretations of grounded theory…" (p. 80). He also offers a stance that is somewhat contradictory to Glaser and Strauss's (1967) position, noting that, when collecting data, sites and sources (e.g., individuals of interest) are selected according to their relevance in the generation of comparisons and extension or refinement of ideas, rather than for their representational value in allowing generalisations to particular populations. Data collection stops when categories reach theoretical saturation; that is, when further data no longer prompts new distinctions or refinements to the emerging theory. Data analysis stops when a core category emerges around which the researcher can integrate the analysis and develop a story encapsulating the main themes of the study (Dey, 2003).

3.1.1.3 *Interviewing*. According to Patton (2002), the purpose of qualitative interviewing is to allow us to enter into the other person's perspective. It begins with the assumption that perspective of others is meaningful, knowable, and able to be made explicit. Arksey and Knight (1999) noted that interviewing is a powerful way of helping people to make explicit things that have hitherto been implicit – to articulate their tacit perceptions, feelings and understandings. By conveying the attitude that the participant's views are valuable and useful, one is more likely to yield useful data from interviewing (C. Marshall & Rossman, 1999).

Seale (1998) identified two major traditions on which the analysis of interviews has centred: Interview data as a resource and interview data as a topic. In the former, collected interview data collected are seen as reflecting interviewees' reality outside the interview. When analysing interview data as a topic, the interview data collected is seen as more-or-less reflecting the interviewee and interviewer's conjointly constructed reality. The mode of analysis adopted would largely hinge on the researcher's epistemology. Thus, if he or she uses an interpretivist approach, then interview data may be viewed as a resource, while a positivistic or pragmatic approach – as in the present research programme – will lead to interview data being viewed as a topic; this approach enables the researcher to identify details with propositions that can be tested or identified in subsequent cases (Chih Lin, 1998).

Patton (2002) advocated the use of (a) an interview guide when conducting interviews, which ensures that the interviewer has carefully decided how best to use the limited time available to him or her; and (b) conversational probes, which he describes as the basic questions that fill in the blank spaces of a response "…"who," "where," "what," "when," and "how" questions that are used to obtain a complete and detailed picture of some activity or experience" (pp. 372-373).

3.1.1.4 *Qualitative data analysis.* Many texts have been devoted to qualitative research and the analysis of qualitative data (Glaser, 1992), and this preoccupation has extended to the analysis of qualitative data in sport (e.g., Côté, Salmela, Baria, & Russell, 1993). The unit of analysis is usually segments of texts that contain some particular meaning, rather than individual words or phrases. These are then coded, sorted, and organized to enable the researcher to look for patterns, or connections, between them; software manufacturers (e.g., QSR International, 2003) have developed packages that make the process considerably more manageable. Regardless of computer use or disuse, the process may be viewed as one of theory building, either thematically or by using the procedures of grounded theory (Fossey et al., 2002). It is preferable to analyse interview transcripts as soon as possible until it is clear that perspectives are being repeated and data saturation reached (D. E. Gray, 2004); this way one can see whether one has anything worth pursuing (Seale, personal communication, January 11 2005).

3.2 Rationale for the Present Study

To date, considerable research has been conducted on the ideal emotional state for performance (e.g., Edmonds et al., 2006), affective responses to music (North & Hargreaves, 1997), and the psychophysical effects of music in sport and exercise (e.g., Karageorghis & Terry, 1997). However, music listening as a pre-performance strategy to elicit facilitative emotions in sport remains largely under-researched. Despite the fact that young people's use of music to regulate their emotional states has been reported (Saarikallio & Erkkilä, 2007), as has habitual music use by athletes (Gluch, 1993), there is still little understanding of the processes by which pre-performance music is selected, or of its intended or actual affective consequences.

3.3 Aim of the Present Study

The main aim of this study was to examine the use of music to manipulate emotional states by young tennis players who indicated the use of music listening as a pre-performance strategy, to gain a better understanding of their emotional responses to music and the factors that mediate these responses. Research on musically-induced emotions (e.g., Gabrielsson, 2001) and music listening in sport and exercise (e.g., Karageorghis & Terry, 1997) were used in conjunction with pilot data to develop a suitable interview schedule (Patton, 2002). Participants recorded their emotional responses to music heard during interview using a variant of Russell, Weiss et al.'s (1989) Affect Grid, and discussed their reasons for selection. Some participants agreed to complete a two-week diary detailing their daily music listening, together with their reasons for listening, and emotional responses, to music. All emergent concepts were incorporated into a model which will provide a template to guide (a) athletes' music selections and (b) future research efforts which seek to identify causal relationships between emotional responses to pre-performance music and performance itself.

3.4 Method

3.4.1 *Pilot Interviews*

Following institutional ethics approval, seven unstructured pilot interviews were conducted with a convenience sample of two women and five men (mean age = 26.1 years, *SD* = 4.7 years), in order to develop a suitable interview schedule, and to inform the first author's interviewing style for the main study. Interviewees participated in a range of sports (rowing, basketball, marathon running, hockey, weightlifting, tennis, and soccer), and represented a range of competencies (recreational to international). Participants were asked generic questions relating to their music use, such as "What do you listen to as part of your pre-performance preparation?", "How do you decide to listen to that choice of music?", and "How does it make you feel?"

The pilot study revealed a potential methodological problem: The difficulty inherent in eliciting information from participants about why they would select any given music track. Very little, if any, conscious thought was given to the underlying reasons for selection of a given track or artist; the reason was largely reduced to a simple, "because I like it". This necessitated the development of suitable elaboration probes (Patton, 2002), such as "What do you like about it?" Pilot study participants also found difficulty in remembering and naming tracks; therefore, participants selected to take part in the main study were asked to complete a pre-interview questionnaire, and were requested to bring five of their pre-performance music tracks to interview.

3.4.2 *Participants*

An international junior tennis centre in southwest London, England, UK, catering to young tennis players from a wide variety of sociocultural backgrounds, was chosen as a suitable site for data collection. It was anticipated that this site would expedite the selection process, facilitate cross-case comparisons, and allow subsequent refinement and extension of ideas emanating from the data (Dey, 2003).

An initial questionnaire (full version in Appendix B) was administered to 67 players at the centre; LTA rating was used as an index of respondents' current ability. Forty-seven players returned the questionnaire and the data collated were used to purposively select players for interview according to a number of informativeness-related criteria: (a) Those participants who had provided questionnaire responses which described their music listening habits in the greatest detail; (b) those with an LTA rating of 5.1 and above, as they occupy the top 10% of all British players; (c) and those who had indicated music listening as part of their performance preparation routine.

Fourteen participants – seven women and seven men (mean age = 18.4 years, *SD* = 1.97 years) who satisfied the inclusion criteria, and had at least 5 years' competitive tennis experience (mean = 7.4 years, *SD* = 2.6 years), were recruited. The ethnicities represented comprised White UK/Irish (*n* = 10), White European (*n* = 2), Afro Caribbean (*n* = 1), and White US (*n* = 1).

3.4.3 *Interview Guide*

Respondents' answers to the initial questionnaire and a literature search highlighted a number of *sensitizing concepts* on which to build a loose interview guide (example questions in parentheses): Music properties ("Are there any particular segments of this track you like?"); extra-musical associations ("Does it make you think of anything?"); sociocultural variables ("How do you think this music is perceived by your peers?"); music-related imagery ("Does this music conjure up any images?"), and listening habits ("Where are your top three places for listening to music?"). It also became apparent during the first interview that the guide should be shorter and less specific; therefore it was amended accordingly (the final version is in Appendix C).

3.4.4 *Interview Materials*

Interviews were recorded using a digital voice recorder (Olympus VN-480PC; Olympus Corporation, Tokyo) and were transferred onto a laptop computer via a software interface (Olympus Digital Wave Player v. 2.0.0; Olympus Corporation, Tokyo) for ease of transcription. In vivo notes were taken, to capture nonverbal information and any key concepts that emerged. The note-taking process also assisted the first author in pacing the interview appropriately (Dey, 2003).

3.4.5 *Procedure*

3.4.5.1 *Pre-interview music questionnaire.* Players selected at the preliminary stage were invited to take part in a 1 hr interview about their music listening habits, and their use of music in the context of tennis. Each participant was given a paper catalogue containing 2,024 music tracks from the first author's personal music collection. These tracks were grouped by genre (e.g., *alternative*, *R'n'B*, *classical*), then alphabetised; all catalogue entries were held in electronic music format. To ensure that performance-related music was discussed at interview, the front sheet of the catalogue requested that participants list five emotional states they deemed crucial for success in tennis, and to specify music tracks which made them either feel or think about each state. Participants were asked to bring along any music tracks not included in the catalogue to the interview. All selected tracks were played during the interview to stimulate discussion.

3.4.5.2 *Interviews.* Participants read a Participant Information Sheet (see Appendix K) and provided written informed consent (see Appendix O). Interviews took place in a quiet room, lasted 37-84.5 min (M = 52.4 min), and were digitally recorded. Music tracks were played from audio software via a stereo receiver (Pioneer SX-205RDS; Pioneer Corporation, Tokyo), which outputted through two 50 W speakers (Pioneer CS-767; Pioneer Corporation, Tokyo) placed 2.2 m apart and equidistant (1.2 m) from the participant. Sound intensity was measured using a digital sound meter[1] (AZ 8928; AZ Instrument Corporation, Taichung City, Taiwan) mounted on a tripod at the participant's head height. Prior to discussion of each selected track, the researcher requested that participants adjust the intensity of the music to

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[1] This device was calibrated using a Brüel and Kjær (Nærum, Denmark) Sound Level Calibrator, type 4231.

one which they would typically apply to engender the named emotional states. They were also requested to rate each track not only for liking and arousal potential (cf. North & Hargreaves, 1997), but also for familiarity and popularity with peers, on 11-point bipolar scales; this was done while listening at a standardised intensity of 55 dBA. It was expected that the combination of qualitative and quantitative data would give a “powerful mix” (Miles & Huberman, 1994, p. 42).

3.4.5.3 *Diary.* Ten of the 14 participants interviewed agreed to complete a 2-week, page-a-day diary (see Appendix D). Participants were informed that seven completed pages would be sufficient, but anything more would be helpful; and that they would receive three text messages on their mobile phone per day: In the morning, at lunchtime, and in the evening. The morning and lunchtime messages served as prompts for the participant to recall and note any music heard up until that point; it was expected that this *preconscious prompting* would facilitate subsequent recall of a behavior that tends to proceed in a relatively habitual – and therefore unmemorable – fashion. The evening message served as a prompt to complete that day’s page; this bears some similarity to the Experience Sampling Method (Larson, 1983), which has been successfully used as a non-invasive tool for gauging athletes’ emotions in the lead-up to competition (Cerin, 2001). Each page required the completion of a brief summary of daily activities carried out while listening to music, and details of a memorable music listening episode on each daily page. It was decided that, although very few music listening episodes would relate directly to music listening *immediately* prior to performance, to have such a narrow focus would provide too little data. Given that music may be an effective moderator of pre-performance mood (Gluch, 1993), that athletes exhibit symptoms of competition-related emotions up to 1 week prior to competing (Hanton, Thomas, & Maynard, 2004), and that all participants were engaged in at least one competitive event during the diary completion period, all music listening episodes were considered relatable to the aims of the study. Participants were asked to log as many episodes throughout each day as they could recall. They rated any music heard during diary completion for both liking and arousal potential.

3.4.5.4 *Observations*. Rapley (2003) asserted that "No form of interview study, however devious or informal, can stand as an adequate substitute for observation data" (p. 29); nonetheless, observable phenomena of music listening are scarce. During playback of each track the first author recorded changes in participants' facial expressions and behavior (e.g., smiling, piloerection, and increased liveliness); in vivo notes on the interview schedule indicated the precise nature and timing of these changes.

3.4.6 *Data Analysis*

Grounded theory (Glaser & Strauss, 1967) was chosen as the appropriate method for both data collection and analysis, because it is a technique for developing theory from actual data. In accordance with the tenets of grounded theory, interviews in the present study were semi-structured, so as to allow for the emergence of novel information offering new directions. While emergent theory was grounded in the raw data, there was inevitable interplay between the first author and the data, which could have led to the identification of themes concordant with the researcher's beliefs, to the exclusion of others. Therefore, a number of precautions were taken to minimise the impact of such biases, most important of which was triangulation (Miles & Huberman, 1994).

Triangulation was achieved by utilising diverse data sources (via selection of a seemingly diverse sample of participants, in terms of gender, age, ethnicity, and musical preferences); multiple data types (written notes, interview transcripts, sound intensity recordings, participant diary notes); an array of methods (interview, diary, observation); and recruitment of other researchers – who did not participate in the data collection process – to assist in data analysis. All raw interview and diary data were given to a peer debriefer who possessed knowledge of both psychomusicology and music listening in sport, to either corroborate or refute the author's interpretations of the raw data, and to suggest alternative explanations. Inter-rater agreement for interview data was 93%, inter-rater agreement for diary data was 95%; this procedure could not be performed for observation data. Other procedures were conducted with regard to trustworthiness criteria in qualitative research (Lincoln & Guba, 1985): The first author was engaged with the data for a prolonged period, persistently observed the participants, identified negative instances, kept a reflexive journal, and gave copies of interview transcripts to participants in order to confirm their representativeness.

3.4.6.1 *Coding procedures*. Interview data were analyzed immediately and compared with existing data (constant comparison; Glaser & Strauss, 1967), in order to establish whether or not there was anything worth pursuing (C. F. Seale, personal communication, January 11, 2005): Recurrent themes (e.g., the presence of memorable life episodes in relation to selected music) emerged after a visual inspection of the first three interview transcripts; this prompted the continuance of data collection, regardless of diary data contribution (the first diary was only returned 2.5 weeks post-interview).

3.4.6.2 *Pre-interview music questionnaire data*. Participants listed a total of 70 emotional states which they deemed crucial to their success in a tennis match. Identical responses across participants enabled immediate reduction into 42 raw data themes (Table 3.1, p. 123), which the author and a peer otherwise uninvolved in the study independently clustered into 16 and 19 first-order themes, respectively. On discussion, it was mutually decided that 18 first-order themes best represented the raw data obtained (inter-rater agreement = 100%). The author and peer independently grouped these themes into five and seven dimensions, and subsequently agreed that five general dimensions ultimately provided the most parsimonious representation of the data.

3.4.6.3 *Interview and diary data*. All interview and diary data were fully coded and analyzed inductively using QSR NVivo (v. 2.0): Complete Word file transcriptions were imported into NVivo, where free nodes (cf. open coding; Strauss & Corbin, 1998) were used to categorise chunks of text. Free nodes were created ($N = 1{,}087$), which were then grouped into 57 trees (cf. axial coding; Strauss & Corbin, 1998). All tree concepts were subjected to a visual inspection, and combined where appropriate in order to develop central categories. The decision to include a concept as a central category was made according to frequency of occurrence: Central categories were chiefly included due to either (a) their occurrence across all participants and all data sources, or (b) their frequent occurrence across data sources only. When the development of categories reached *theoretical saturation* (Strauss & Corbin, 1998) data collection ceased. In accordance with Strauss and Corbin's (1998) guidelines for selective coding, all central categories were incorporated into the model in Figure 3.2, so that the findings could be presented as a set of interrelated concepts.

3.5 Results

The initial questionnaire, pre-interview music questionnaire, interview, and diary collectively yielded qualitative and quantitative data pertaining to the *how*, *what*, *when*, *where*, and *why* of participants' music listening. Figure 3.2 depicts an integration of all emergent concepts into a process model; these concepts are elucidated below.

3.5.1 *General Overview of Participants' Listening Habits*

Initial questionnaire data indicated that participants enjoy listening to *Indie*, *Light Rock*, *Rap*, *R'n'B*, *Garage*, *Rock*, *Easy Listening*, *Dance*, *Old Skool*, *Love Songs*, *Hip-hop*, *Techno*, and *Alternative*.[2] The overlap between many of these categories (e.g., Old Skool and Hip-hop) reflects the growing implicit perception of music as a homogenous entity (North, Hargreaves, & Hargreaves, 2004). Data also indicated that participants used music to *psych-up*; to feel more positive, motivated, and confident; and to dissociate from external stressors. All questionnaire responses can be found in Appendix E.

Interview and diary data indicated that participants listened to music daily, for two hours or more, on average. Data from the initial questionnaire, interviews and diary pages

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[2] A full listing of genres is available on request from the author responsible for correspondence.

triangulated to suggest that participants were mostly travelling (predominantly in a car), preparing for tennis (including in the locker room), in their bedrooms, or working out in the gym when listening to music. All participants listened to commercial radio stations and watched music video channels (e.g., *MTV*) daily when at home.

3.5.2 *Music Selection*

Central to the present data, and the model in Figure 3.2, is that participants purposely selected music to attain a desired emotional state. This was initially borne out in the initial questionnaire, and participants’ responses to the pre-interview music questionnaire indicated that they deliberately selected music to elicit five broad categories of emotional states:

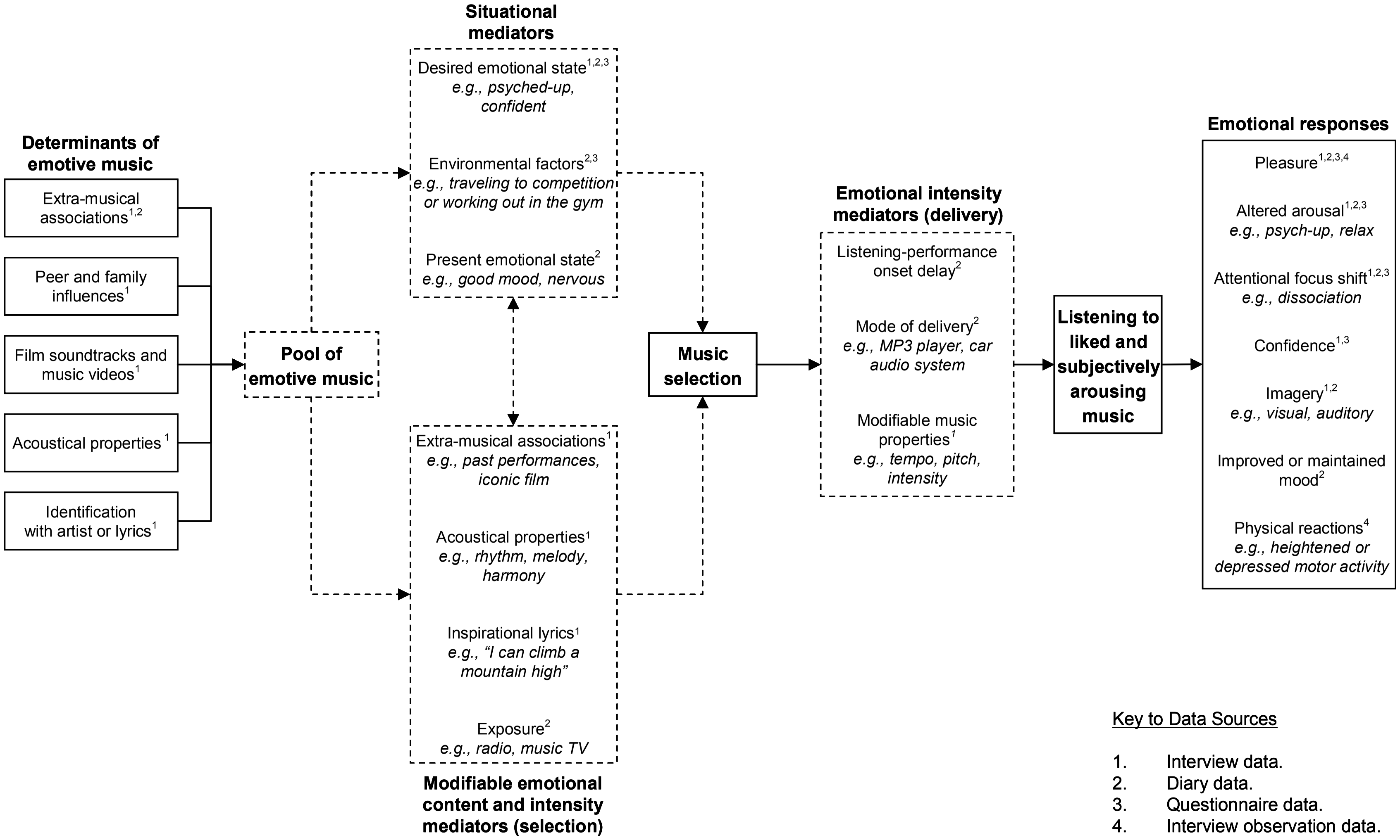

Figure 3.2. A model of young tennis players' use of music to manipulate emotional state.

Appropriate mental focus, *confident*, *positive emotional state*, *psyched-up*, and *relaxed* (see Table 3.1). This too was corroborated, by interview data:

I listen to this a lot before I go to matches and before matches, together with the last track, being the last song I've heard, when I get out of the car, to give me that feel-good factor. (Participant 14)

> Sometimes, when…I'm playing bad, I might bring out my *iPod*, like at a changeover, and maybe listen to this song, to give me a confidence boost....Or if I'm [annoyed], I'll listen to a relaxing song that will make me chill out. It helps a lot. (Participant 9)

This use of music had been developed by some participants to such an extent that they used a medley of tracks in an attempt to optimize their emotional state:

> On the way, I'll listen to a specific selection of CDs. I'll listen to Ashlee [Simpson], Justin [Timberlake], and…Christina Aguilera. (Participant 2)

The five categories of reported emotional outcomes of music listening were integrated into the final stage of the model in Figure 3.2.

> The thing is [tracks] 1, 2, 4 , and 5 are needed to feel [confident]. So I was trying to find a song that makes me feel [confident], but there isn't one song that does that. But listening to all of these four songs makes me feel these four things, which makes me feel confident. I haven't found a [single] song yet which makes me feel confident. (Participant 4)

3.5.3 *Determinants of Emotive Music*

Interview data indicated that five factors repeatedly occurred across and within participants, to determine the likeability and arousal potential of participants' *pool of emotive music*: *Extra-musical associations*, *peer and family influences*, the involvement of the music in *film soundtracks and music videos*, *acoustical properties*, and *identification with artist or lyrics*.

Table 3.1

Intended Emotional Outcomes of Music Listening

Raw data themes (*k* = 42)	First-order themes (*k* = 18)	General dimensions (*k* = 5)
Able to focus Accept bad shots and move on Concentration	Ability to focus	Appropriate mental focus
Clear mind Clear under pressure	Clear mind	
Clearly focused Focused Zoned in Keyed in	Focused	
Mentally in control Mentally prepared Prepared	Mentally prepared	
Belief and confidence	Self-belief	Confident
Confident Fearless, courageous	Confident	
Remembrance of previous good play	Past performance success	
Feeling fresh	Feeling fresh	Positive emotional state
General happiness	Feeling happy	
Positive Positive attitude Positive/happy	Positivity	
Tough (mentally)	Mentally tough	

(*table continues*)

Table 3.1 (continued)

Raw data themes ($k = 42$)	First order themes ($k = 18$)	General dimensions ($k = 5$)
Energised	Energised	Psyched-up
Excited/eager		
Fire it up		
Motivated	Driven to win	
Wanting the satisfaction of winning		
Determined		
Motivated (ready for anything)		
Never give up		
Prepared for a fight		
Willing to fight to end		
Up for it		
Psyched-up	Psyched-up	
Pumped-up	Pumped-up	
Pumped		
Calm	Calm	Relaxed
Calm thinking		
Calmness		
Loose/“no worries”	No worries	
Relaxed	Relaxed	
Relaxed/chilled/breathe		

3.5.3.1 *Extra-musical associations.* Extra-musical associations with significant persons, places, or past events were a prominent feature in many (49/70) of the tracks selected by participants. These associations were often formed as a result of single-trial conditioning:

> Can you hear it? The football? He says the bit, "…they've taken the lead in the European Championship final", and whatever. It just reminds me of Euro 2004 [soccer championships], Greece winning it.…it like, brings back happy memories, helps me forget about everything else. (Participant 10)

There was also evidence of participants specifically associating tracks with good past performance:

> I'm choosing *Another Day* because that reminds me of this girl called [Lauren]…. I wanted to use a word that means something to me; I couldn't use *fight*…. I wanted something that's going to be mental arousal on different levels…. So that's why I use John Secada, because it reminds me…of good tennis. (Participant 8).

> If I listen to this song before a match, and I play really well…if I hear it again, then I'll think of stuff in the match, how well I did, if I'm just like in my room. (Participant 11)

Participants could also provide specific details of associated significant places, events or others associated with the memorable music tracks which they described on diary pages (Table 3.2, p. 123).

3.5.3.2 *Peer and family influences.* Some participants indicated that their peers or family members introduced them to a music track:

> I never used to like Matchbox 20, I used to hate music like that, then [a friend] introduced me to one track of theirs, and I thought I'd give it a shot, and now I like listening to it…. It's weird how things change. (Participant 9)

All tracks were rated as popular with peers, with the exception of those selected to elicit a positive emotional state (see Table 3.3, p. 128):

> Oh, again, no, they won't like this. Then again, that's something that I pride myself on…I don't really care what other people think…if it's cheesy, I don't care. (Participant 8)

3.5.3.3 *Film soundtracks and music videos.* Film soundtracks were highly prevalent in the musical selections provided by participants. This extended to some now clichéd tracks from the *Rocky* film series, four of which were on general release before 12 participants had been born:

> I love those movies because my dad said, when I was about 13, you really should watch Rocky. He put it on one morning, and I just loved it…. I'm not a massive fan, but you can watch it any time, it just gets you so pumped up, and the song just sticks, and it…just gets you….pumped-up for anything. (Participant 4)

> [because] it reminds me of…how I've been preparing…I've got to the match and I've prepared myself, and…in the Rocky films, this is the music when he was training for his fights, this is the music he was listening to. And when I'm doing my training, I listen to this as well. (Participant 6)

Other participants selected tracks from films without sporting connotations:

> I heard it in Johnny 5...the Short Circuit film...I saw it quite recently, [because] I haven't seen it since I was really little, and we always really liked it. I saw it quite recently…at the end it's really good… (Participant 3)

All participants watched music video channels, and the videos accompanying music tracks were often easily recalled:

Table 3.2

Diary Data: Situational Mediators and Emotional Outcomes of Music Listening

Item	Illustrative quotations	First order theme	General outcome
Why did you choose to listen to this particular track/artist/type of music?	“Because it gives me a lot of energy and it gets me going.”	To get pumped or psyched-up (*n* = 12)	Psyched-up (n = 12)
	“I use it to get me fire up (I had match practice this day).”		
	“Just to relax me, unwind myself and chill out, clear my mind.”	To relax or calm down (*n* = 11)	Relaxed (n = 11)
	“Because I just wanted to listen to some music that I find relaxes me.”		
	“Just as background music, no particular preference, just let the music play.”	To accompany another activity (*n* = 8)	Attentional focus shift (n = 16)
	“While I’m writing this it just gives me something else to do while I’m writing down.”		
	“I was super, super bored.”	To alleviate boredom (*n* = 7)	
	“Had listened to the rest of the CDs, and fancied a bit of a change. It was a bit faster…”		
	“Just to take my mind off the traffic, the pressure of the tournament, draw, etc.”	As a distraction (*n* = 1)	

(*table continues*)

Table 3.2 (continued)

Item	Illustrative quotations	First order theme	General outcome
How did you feel BEFORE hearing it?	“Good mood, [because] I was very relaxed and it was such a nice day.”	Good mood ($n = 18$)	Positive mood ($n = 25$)
	“Good mood, positive and confident.”		
	“Ok.”	Okay ($n = 7$)	
	“I was in an OK mood, but as usual music made working out much easier!”		
	“I felt a bit tired and quiet.”	Tired ($n = 18$)	Negative mood ($n = 27$)
	“A little tired. I’m not good at waiting around, so I was a little bored.”		
	“Bad mood.”	Bad mood ($n = 4$)	
	“I felt…a bit annoyed because I had to pull out of [a tournament].”		
	“Slightly down.”	Depressed ($n = 3$)	
	“Slightly depressed and very tired.”		
	“I was nervous before listening to the music.”	Nervous ($n = 1$)	

(*table continues*)

Table 3.2 (continued)

Item	Illustrative quotations	First order theme	General outcome
	"…I became happy, laughing."	Good mood ($n = 22$)	Improved or maintained mood ($n = 24$)
	"The music as usual made me feel a lot better."		
	"None really."	No change ($n = 2$)	
	"No change."		
What effect did the music have on your mood/behaviour, if any?	"Feeling good, Pumped up!"	Pumped / psyched-up ($n = 18$)	Psyched-up ($n = 18$)
	"…the music made me forget the tiredness a bit and pumped me up."		
	"This music by [artist] always helps me to relax and unwind."	Calm / relaxed ($n = 8$)	Relaxed ($n = 8$)
	"It just relaxed me, and I don't think I thought about anything while listening to it."		

(*table continues*)

Table 3.2 (continued)

Item	Illustrative quotations	First order theme	General outcome
What do you associate with this music?	“Being home in East London.”	Places ($n = 10$)	Places or events ($n = 16$)
	“Usually in my dad’s car on the way to a tennis match.”		
	“I now associate it with that rugby match.”	Events ($n = 6$)	
	“Dancing in a club.”		
	“The Aussie guys in my house, who were singing very funnily to it.”	Friends ($n = 13$)	Significant others ($n = 15$)
	“A friend I went to school with, because he wrote it for me.”		
	“My sister. It reminds me of when we go to our favourite club in Liverpool.”	Family ($n = 2$)	
	“Nothing I can think of.”	Nothing ($n = 11$)	Nothing ($n = 11$)
	“None.”		

> …she's in this house, like Alice in Wonderland, and I just think of that every time I hear this song, I don't know why. It's just something that sticks in my mind. (Participant 5)
>
> …she's got black wings on. She's just walking around singing it, and he's dragging his guitar. But apart from that, it's just like a deserted caravan park… (Participant 3)

3.5.3.4 *Acoustical properties.* The properties of the tracks were cited as factors influencing participants' selection of music:

> …it's a really soothing tune. It doesn't, like, work me up, and it doesn't like, go over the top; it's just nice and level. (Participant 11)
>
> It just makes me relaxed. It's not very loud, it's not heavy beats, heavy bass, it's just very like, relaxed. (Participant 9)
>
> And also I like this bit; it's in the middle of the song, and it changes, and she holds the same note for a long time, and again, it like builds up and then it's back to the words again that make me feel that I can accomplish things. (Participant 12)

3.5.3.5 *Identification with artist or lyrics.* There was evidence that participants listened closely to the lyrics of their selections and empathized with the artists (cf. Scherer & Zentner, 2001); further, that this formed part of the decision-making process when selecting tracks:

> This is, again…the lyrics of this song, I think, make a lot of girls feel confident. She's basically talking about, "Boyfriend, there you go, and don't come back!" She's really standing up for what she thinks. (Participant 11)
>
> Um, there's like, "I can climb a mountain high"…. It's just like, I can do anything, I can achieve anything. It makes me think of that when I listen to it. (Participant 12)

Table 3.3

Quantitative Data for Participants' Personal Music Selections

Emotional state (no. of responses)		Selected intensity/ dBA	Tempo/ bpm	Liking[1]	Arousal potential[2]	Familiarity[3]	Popularity with peers[4]
Appropriate mental focus ($n = 15$)	Mean:	93.8	101.3	10.2	8.7	9.5	7.7
	Median:	88.4	96.0	10.0	9.0	10.0	8.0
	Mode:	N/A	96.0	10.0	10.0	11.0	10.0
Confident ($n = 16$)	Mean:	98.8	113.0	9.6	9.0	9.2	7.1
	Median:	104.6	111.0	10.0	9.0	10.0	7.0
	Mode:	108.9	96.0	10.0	9.0	10.0	6.0
Positive emotional state ($n = 7$)	Mean:	93.1	114.0	10.3	9.7	9.3	5.3
	Median:	84.6	126.0	10.0	10.0	10.0	5.0
	Mode:	N/A	N/A	11.0	10.0	10.0	3.0
Psyched-up ($n = 21$)	Mean:	102.3	120.9	10.2	10.5	8.9	6.6
	Median:	108.7	132.0	11.0	11.0	11.0	6.0
	Mode:	108.9	90.0	11.0	11.0	11.0	9.0
Relaxed ($n = 11$)	Mean:	87.9	87.9	10.6	9.2	9.9	6.9
	Median:	88.6	84.0	11.0	10.0	10.0	8.0
	Mode:	N/A	72.0	11.0	10.0	11.0	9.0

[1]5 = not at all liked; 11 = +5 = highly liked. [2]-5 = not at all energizing; 11 = +5 = highly energizing. [3]-5 = not at all familiar; 11 = +5 = highly familiar. [4]-5 = not at all popular; 11 = +5 = highly popular.

3.5.4 *Emotional Responses to Music*

All personal music tracks discussed in interview – without exception – were rated as being highly liked, possessing high arousal potential, and being highly familiar (see Table 3.3); this was irrespective of the intended emotional outcome. Participants' mean ratings for liking and arousal were located in the upper-right quadrant of Russell, Weiss et al.'s (1989) Affect Grid. Tracks chosen for psyching-up were played at the highest intensities and exhibited faster tempi than tracks selected for other emotional outcomes; tracks selected in order to relax were lower, on average (see Table 3.3).

Three broad categories of emotional responses to music listening – intended or reported – emerged as primary themes in diary data (see Table 3.2). Participants indicated that they used music in order to *psych-up*, *relax* and/or to promote an *attentional focus shift*; feeling more *psyched-up* or *relaxed* and *improved or maintained mood* were frequently reported outcomes. All participants reported *imagery* in response to music heard during interview and exhibited overt *physical reactions*.

3.5.4.1 *Imagery.* Participants used vivid description of visual images when listening to music during interview, and sometimes appeared to reminisce:

> I can actually picture one of the goals I scored when this is playing…..I just can't think of anything bringing back such a strong memory as this song….it's so vivid, especially if I close my eyes, especially when I'm listening to this song. I remember the goal I scored, the pitch we were playing on, I remember everything…(Participant 8)

Participants also described auditory imagery, which can be described as "hearing in the mind's ear" (A. P. Moran, personal communication, September 5, 2005): Participants remarked that they sing along to various tracks, even in the absence of the physical stimulus; this extended to hearing the song in their mind's ear while on court:

> Yeah, I sing on court….It would be California, or a specific one. It would be specific phrases in my head. (Participant 2)

3.5.4.2 *Physical reactions*. Given that emotional responses have behavioural and facial expression components (Frijda, 1986; Russell & Bullock, 1985), participants' reactions to music tracks were noted and subsequently incorporated into the model (see Figure 3.2). The most frequently observed reactions were smiling (in response to 58 out of 70 tracks), increased motor behavior (24/70), and piloerection (7/70); however, these responses did not differ as a function of the intended emotional outcome of each music selection.

3.6 Discussion and Conclusions

3.6.1 *Overview*

The main objectives of this study were (a) to examine the use of music to manipulate emotional states by young tennis players who indicated the use of music listening as a pre-performance strategy, in order to gain a better understanding of their emotional responses to music and the factors that mediate these responses; and (b) to put forward a model grounded in present data which will provide a template to guide not only athletes' music selections, but also future research efforts which seek to identify causal relationships between emotional responses to pre-performance music and performance. Qualitative and quantitative interview and diary data were combined to generate a grounded theory of this phenomenon. Grounded theory (Glaser & Strauss, 1967) was considered the best method, because such an approach is most likely to enhance our understanding and to guide subsequent action (Strauss & Corbin, 1998).

Central to the present data is the fact that all participants selected music to manipulate their emotional state. Music selections were highly idiosyncratic: Considerable interindividual differences existed in the genre and style of tracks selected to achieve identical emotional states. For example, Participant 1 selected *Still D.R.E.* by Snoop Dogg and Dr. Dre in order to feel confident, while Participant 2 selected *Bootylicious* by Destiny's Child to achieve the same end; and some participants used a medley of tracks in an attempt to attain an ideal emotional state, consistent with the notion that idiosyncratic emotional profiles are necessary for successful sporting performance (Edmonds et al., 2006). Given the facts that (a) research has shown that emotional profiles fluctuate considerably in the week leading up to competition (Hanton et al., 2004), (b) music listening pervaded daily diary entries, and (c) improved/maintained mood was an oft-cited consequence of music listening, stricter control of music heard in the lead-up to competition may be an important strategy for regulating young athletes' pre-performance mood; a notion supported by work examining non-athletic populations (Saarikallio & Erkkilä, 2007; R. E. Thayer et al., 1994).

3.6.2 *Determinants of Emotive Music*

The determinants of participants' emotive music in the present model can be delineated according to Sloboda and Juslin's (2001) classification of extrinsic and intrinsic sources of emotion in music: Four of the five determinants can be classified as extrinsic factors; *acoustical properties* are intrinsic. Extrinsic sources of emotion were mentioned more frequently, and with greater description, than intrinsic sources. Participants' music selections were also highly idiosyncratic (typified by a broad range of artists and genres represented), which may reflect the inescapably unique combination *of peer and family influences* on an individual's familiarity with music (cf. North & Hargreaves, 1995). Music also offers young people the opportunity to create a strong, albeit often temporary, self-identity (Larson, 1995), which participants in the present study were able to project onto/draw from the artists' performance of the selected tracks (empathy; Scherer & Zentner, 2001). Indeed, the comparatively low ratings for *popularity with peers* across all tracks (see Table 3.3) corroborates this notion. Therefore, extrinsic sources appear to be stronger determinants of emotional content than do the acoustical properties, as per Sloboda and

Juslin’s (2001) assertion. Extra-musical associations featured strongly in both interview and diary data. It may be viable to promote these associations through the creation of personal music videos: A music track which has been paired with a motivational and technically exemplary video may elicit a (learned) dispositional representation (Damasio, 1994) of a facilitative emotional state (memory route; Scherer & Zentner, 2001).

3.6.3 *Mediators of Emotional Responses to Music*

While some data were evidently determinants of, or responses to, music listening, other recurrent data concepts were not so clearly delineated. These concepts, derived from interview data, questionnaire data and diary data, were combined with extant research (e.g., Scherer & Zentner, 2001) to develop a set of theoretical mediatory factors for inclusion in the model (demarcated by dashed lines). They were included so that process – an essential part of Strauss and Corbin’s (1998) approach to theory building – could be incorporated into the model.

Diary data indicated three potential *situational mediators* of liking and arousal potential. Participants had a *desired emotional state* to attain, largely to *psych-up*, *relax*, or *dissociate*, which suggests that improvement of emotional state was an important regulatory goal (cf. Saarikallio & Erkkilä, 2007); and their *present emotional state* was quite often negative, indicating that music more frequently served to enhance mood (cf. R. E. Thayer et al., 1994). Further, all data sources uncovered a diverse array of listening environments; these included in the *car*, *train*, and *locker-room*; *on-court*; and *in the gym*. Given the interaction between affective visual and auditory stimuli (Baumgartner, Lutz et al., 2006), the impact of music might have been diminished or enhanced by such *environmental factors*. Thus, prescription of music listening as a pre-performance strategy should take the athlete’s visual environment into account.

Three *determinants of emotive music* were considered modifiable, in that the performer is able to base their instantaneous selection upon these factors, in order to manipulate the content and intensity of the experienced emotions. They were *extra-musical associations*, *acoustical properties*, and *inspirational lyrics.* Because (a) all participants watched music video channels and listened to commercial radio stations, and (b) evidence exists for a positive relationship between exposure and music preferences (North & Hargreaves, 1995; Witvliet & Vrana, 2007), *exposure* was also included as a potentially influential mediator. This refers not only to the frequency and volume of exposure to music tracks, but also to the pairing of tracks with a strongly emotive event in the past; this potent memory route to emotion induction may override those produced via other more deliberative (cognitive) mechanisms (Scherer & Zentner, 2001).

Once a music track has been selected, there is potential to modify some physical attributes of the listening situation at the delivery stage, to mediate the experienced emotional intensity. Pre-competitive emotions may persist and fluctuate over the course of one week (Hanton et al., 2004); therefore, *listening-performance onset delay* was included in the model. According to Sloboda and Juslin (2001), the intrinsic music property of tempo is one of the most potent determinants of emotional response. Contemporary technology affords the music consumer the opportunity to manipulate such *modifiable music properties*; and the *mode of delivery* (e.g., iPod via headphones) considerably affects the fidelity of the reproduction of the original sound (contextual features; Scherer & Zentner, 2001). Also, the global proliferation of MP3 players means that music consumers are afforded a unique individualized auditory environment, regardless of location. This portability has important implications for an athlete’s perception of, and affective response to, his or her environment – external or internal (Baumgartner, Lutz et al., 2006; Copeland & Franks, 1991). Hence, *modifiable music properties* and *mode of delivery* were important additions to a contemporary model of music listening in sport.

3.6.4 *Quantitative Data*

Players unanimously rated all selected tracks as highly liked ($M = 10.1$) and highly arousing ($M = 9.3$), regardless of intended emotional outcome, including tracks purportedly selected for relaxation. This finding is comparable that of Saarikallio and Erkkilä (2007), whose participants used music predominantly to strengthen positive feelings, to move away from negative feelings, and to increase emotional intensity (cf. R. E. Thayer et al., 1994). However, the present quantitative data may also reflect the nature of a sport that is intensely competitive, and requires frequent and intense bursts of energy; *relaxed* in this context may refer to players' game styles, as opposed to complete psychophysical relaxation:

> So, in my mind, I feel like I've got to be calm and relaxed, but I've still got to have energy, and, like run down balls and things like that. So it reflects how I want to be in a tennis match. (Participant 12)

Although the circumplex model and its derivatives (e.g., the Affect Grid, Russell, Weiss et al., 1989) may be expeditious measures for assessing emotional responding in vivo, they may do little to assess the diversity of musically-induced emotions: When required to do so, individuals can identify subtle variations in emotional content, which are not fully explained by a dimensional model (Collier, 2007). Therefore, future research should seek to complement circumplex-based measures with discrete emotion labels.

The tempo of tracks associated with relaxation was also noticeably lower than for tracks selected for other emotional outcomes. Conversely, tracks associated with *psyched-up* were played at a higher intensity and exhibited faster tempi than all other tracks, consistent with Scherer and Zentner's (2001) suggestion that proprioceptive feedback prompts the individual to prefer a coupling of internal rhythms with external drivers. This is also supported by Karageorghis, Jones et al.'s (2006) research into the relationship between exercise heart rate and preferred music tempo, in which a moderate correlation between the two emerged. However, these quantitative data contrast somewhat with the high subjective arousal values provided for all tracks used to relax. This appears to reinforce the notion that strong emotional experiences with music are influenced by situational, music, and personal factors (Gabrielsson, 2001), and somewhat reflects Saarikallio and Erkkilä's (2007) unification of *relaxation* and *getting energy* goals of music listening into an ultimate regulatory strategy of *revival*.

3.6.5 *Emotion Valence and Intensity in Responses to Music*

Modern MP3-playing technology features such as *time scaling* enable the user to alter the tempo of a track without affecting other properties such as the pitch. This may mean that the same track can satisfy a greater number of pre-performance needs. Athletes can moderate both the intensity and content of experienced precompetitive emotions by manipulating the intrinsic (e.g., tempo) and extrinsic (e.g., extra-musical associations) properties of their music selections according to the demands of the sport or subcomponent of that sport. J. F. Thayer and Faith (2001) noted that "Valence represents the evaluative outcome necessary to initiate an approach or withdrawal response, and arousal reflects the investment in the directional tendency" (p. 456; cf. Frijda, 1986). Therefore, a loud, fast, and highly disliked track may be subject to not only aesthetic appraisal as unpleasant, but also transactional appraisal as potentially harmful (cf. Scherer, 2004), resulting in reorienting motor responses (cf. Zentner & Kagan, 1996).

Valence is considered a fundamental component of emotional life (e.g., Russell, 1980) and happiness – a key component of the feeling of pleasure – is a key emotional construct in contemporary sport emotion research (Jones et al., 2005). The recurrence of liking and/or pleasure throughout all stages of data collection corroborated the presence of positive *or* negative valence in all recorded emotional responses, irrespective of specific content – but never the coexistence of the two – which some researchers argue is a fundamental feature of affective experience (e.g., Tellegen et al., 1999). Diary responses indicated improved or maintained mood as a consequence of music listening, consistent with past research (R. E. Thayer et al., 1994). However, exercise intensity was not a limiting factor as in previous studies (e.g., Tenenbaum et al., 2004); the majority of music listening episodes occurred independently of physical conditioning sessions. Pleasure was also a persistent theme in observation of participants' facial expressions: Participants smiled in response to the majority (83%) of music selections, which is perhaps unsurprising when considering the unanimously high valence ratings across all music selections. Russell and Bullock (1985) demonstrated that preschoolers and adults rated emotional facial expressions similarly, despite the relative paucity of emotion labels available to the preschoolers: All participants' ratings aligned in an approximate circular structure lying in a two-dimensional space demarcated by pleasure-displeasure and arousal-sleepiness continua. It appears that smiling is therefore one of the most consistently reliable and accessible indicators of positive emotion available to researchers.

3.6.6 *Imagery Responses*

Visual imagery is an important strategy by which athletes can regulate their emotions (Jones, 2003), and it emerged as a theme in interview data. However, the present participants also reported auditory imagery as a consequence of music listening (i.e., singing to oneself). Auditory imagery obeys the same neural principles as visual imagery: Association cortex reconstructs the original percept, such that it is possible to "have a song on the brain" in the absence of the physical stimulus, especially when the track is familiar (Kraemer et al., 2005). Therefore, singing the lyrics of a familiar music track to oneself may be another powerful means for activating Damasio's (1994) learned dispositional representations, such that a performance-facilitating emotional state can be achieved; the combination of emotive music with video may be more powerful still (Baumgartner, Lutz et al., 2006).

3.6.7 Attentional Focus Shift

At all stages of data collection, participants reported an attentional focus shift through music listening; diary data (Table 3.2) suggests that this was primarily dissociative, in line with past research (Szabo et al., 1999; Tenenbaum et al., 2004). Singing – internally or externally – may not only enable athletes to dissociate from stressors in the competitive environment but could also function as part of a pre-performance routine to promote automaticity (Singer, 2002); this can be considered an *active* attentional manipulation which renders over-deliberation unviable, thereby safeguarding against choking (Baumeister, 1984). Given that attentional focus is free to fluctuate, an appropriate progression for the present model would be the inclusion of a neurophysiological intermediary pathway. Music neurophysiology researchers are increasingly addressing neural correlates of emotional responses to music (e.g., Menon & Levitin, 2005), and widespread availability of neural mapping techniques such as functional magnetic resonance imaging means that sport psychologists can now closely map the relation between pre-performance music and emotional responses; this may include the investigation of the neural regions activated when attending to music or when attending to visual stimuli immediately post-music listening.

3.6.8 *Limitations*

Facial expression data in the present study were somewhat limited, which is unfortunate when considering the universality and predictive value of facial expressions of emotions (Ekman, 1972; Russell & Bullock, 1985). This was due largely to the absence of electromyographic (EMG) measures. However, the predominance of smiling as a response to music listening is supported by Witvliet and Vrana (2007), who found that participants' zygomatic (smiling) EMG activity was greater for high-arousal positive music than for all other music; corrugator (frowning) activity was decreased with increased exposure to/familiarity with all music. Participants in the present study only selected highly familiar music; therefore the emotions being expressed – facially or otherwise – were predisposed to be highly positive.

Another methodological limitation of the present study was the fact that only 2 of the 14 participants had sufficient knowledge of musical structure to articulate some of the properties of the music they had selected. This rendered description beyond simplistic terms such as "I like the beat" difficult. As a consequence, it was difficult to accurately discriminate the role of different intrinsic sources in determining participants' emotional responses to their music selections. The use of an instrument such as the BMRI-2 (Karageorghis, Priest et al., 2006) may circumvent this. Participants rated personal music as highly liked and highly arousing; therefore, correlating BMRI-2 scores with scores from the Affect Grid (Russell, Weiss et al., 1989), for example, may enable us to more accurately identify the relative contributions of extrinsic and intrinsic sources to athletes' emotional responses to highly liked, highly arousing music.

3.6.9 Summary

In summary, one of the most notable and recurrent themes throughout all stages of data collection was the active use of music as an emotional regulation strategy, corroborating past findings (Gluch, 1993). A host of environmental and contextual factors appear to influence an individual's music preferences, culminating in a highly individualized *portfolio* of music tracks. Although components within the first stage of the model will serve to sensitize the practitioner or athlete to the selection of appropriate music, there is low potential here for intervention. Conversely, the factors for consideration at the music selection and delivery stages are easily manipulable, and represent a potentially fruitful avenue for future investigation. For example, increasing the tempo and/or intensity of a musical excerpt may increase the magnitude of an affective response and concomitant action tendencies (Frijda, 1987) such as increased motor behavior. This component of the fight-flight response not only relates to Damasio’s (2000) life-preservation role for emotions, but could also mean the difference between sporting success and failure.

CHAPTER 4: THE AFFECTIVE AND BEHAVIOURAL CONSEQUENCES OF MANIPULATING EMOTIONAL STATE VIA MUSIC LISTENING

4.1 Introduction

Music plays an integral role in adolescents' lives (North, Hargreaves, & O'Neill, 2000), and in the development of their social identity (Larson, 1995). Research into the emotional impact of music listening is burgeoning (Scherer, 2004; Witvliet & Vrana, 2007), most notably to further our understanding of neurophysiological emotion phenomena (Gosselin, Peretz, Johnsen, & Adolphs, 2007; Menon & Levitin, 2005); and recent developments in digital music products such as the iPod have empowered young people to moderate the content and intensity of their emotions via "micro-management of personalised music" (M. Bull, 2005, p. 343). Listening to music appears to be an effective behavioural strategy not only for regulating mood, but also for increasing energy (R. E. Thayer, Newman, & McClain, 1994), a finding which extends to adolescent populations (Saarikallio & Erkkilä, 2007). Despite music's ubiquity, portability, and apparent impact on young people's emotional state, its effects on athletes' emotions and subsequent sport performance have not been investigated.

Models have been developed to illustrate the potential of music to manipulate emotional state (Saarikallio & Erkkilä, 2007; J. F. Thayer & Faith, 2001), and to facilitate the study of music use in sport and exercise environments (Karageorghis, Priest et al., 2006; Karageorghis, Terry, & Lane, 1999). Listening to music during physical performance has been shown to enhance affective states (Boutcher & Trenske, 1990; Copeland & Franks, 1991), and this may impact upon muscular strength (Karageorghis, Drew, & Terry, 1996), muscular endurance (Crust & Clough, 2006), and work output (Atkinson, Wilson, & Eubank, 2004); although the mechanisms underlying these phenomena have not been explicated.

Listening to music may also improve subsequent spatiotemporal performance. Rauscher et al. (1993) first reported the Mozart effect, when their participants demonstrated enhanced spatiotemporal reasoning ability after listening to Mozart's sonata for two pianos in D major, K.448. Participants' mean spatial IQ scores were 8-9 points higher after listening than after relaxation instructions or silence conditions. However, subsequent observations yielded inconsistent findings (e.g., Schellenberg, 2001). Explanations for the effect range from mood and/or arousal changes (Ho, Mason, & Spence, 2007) to more precise neurophysiological indices of activity in areas involved in spatial-temporal reasoning (Sarnthein et al., 1997) and other higher cognitive processes (Bodner, Muftuler, Nalcioglu, & Shaw, 2001).

In the previous study of the present programme, a model was developed to illustrate young tennis players' use of music to manipulate their emotional state, as a part of their pre-performance routine (Bishop et al., in press); an array of intrinsic and extrinsic sources of emotion in pre-performance music were identified. In light of evidence for (a) the intrinsic factors upon the emotional impact of music (Dalla Bella, Peretz, Rousseau, & Gosselin, 2001), (b) the mediatory effects of emotions on sports performance (Cerin, 2003; Jones, Lane, Bray, Uphill, & Catlin, 2005; Terry, 2004) and spatial task performance (Rauscher et al., 1993), and (c) the often strong intensity of emotional responses to music (Gabrielsson, 2001), the examination of the interrelationships between intrinsic properties of music heard, affective responses to this music, and subsequent performance seems warranted.

4.2 Rationale for the Present Study

Prior to the current programme of research, the investigation of music in sport and exercise contexts had been largely confined to the exercise domain. A central aim of the first study was to combine qualitative and quantitative methods in generating a theoretical model of the use of music in a sport environment, upon which subsequent research could build. The present study was conceived in order to examine specific components of the model, with the aim of establishing links between intrinsic sources of emotion in music, affective responses to manipulation of these sources, and subsequent sporting performance. Specifically, the variables of intensity and tempo of a researcher-selected track will be modified, to investigate the effects on emotional response and choice reaction time (CRT) performance. CRT will be used as a suitable marker of performance in tennis because it is a crucial variable in the return-of-serve scenario; one which determines the receiving player's ability to successfully execute a return.

When considering the emotional impact of music listening, one must consider both intrinsic and extrinsic sources of emotion (Sloboda & Juslin, 2001). Both sources appeared to play a role in participants' preferences and performance-related selections in the previous chapter of the present research programme. Participants also selected music with faster tempi in order to *psych-up*, and chose high intensities when asked to select a volume at which they would play these tracks in order to attain this state. These intrinsic properties of the music stimulus may mediate both affective valence and intensity, perhaps via an *iconic representation* of psychophysiological arousal (cf. Sloboda & Juslin, 2001) or via *proprioceptive feedback* (Scherer & Zentner, 2001). Faster tempi have been associated with more positive valence: Webster and Weir (2005) examined the interaction of tempo (72, 108, and 144 bpm), texture (harmonised vs. non-harmonised) and mode (major vs. minor) on listeners' affective responses, and found that music played in major modes, at faster tempi, with harmonised melodies, elicited happier responses in the listener; Dalla Bella et al.'s (2001) earlier study suggests that tempo is used as an indicator of emotional tone earlier in a child's development (at approximately 5 years) than is mode.

Intensity and tempo also appear to moderate the arousal component of emotional responses to music (Schubert, 2004). Degree of emotional arousal can predict heart rate, and cardiovascular activation after a person experiences negative emotions appears to last for longer than after they experience positive emotions (Brosschot & Thayer, 2003). Recall and reliving of the primary emotions of fear, anger, sadness, and happiness can lead to significant cardiorespiratory changes for all four emotions relative to a neutral condition, and these changes can differentiate the emotions to some degree (Rainville, Bechara, Naqvi, & Damasio, 2006). Therefore, heart rate will be included as a simple physiological measure of cardiovascular activation accompanying any affective changes observed in the present study.

The tempi of music tracks in the present study will approximate Gaston's (1951) delineations of stimulative (> 130 bpm) and sedative (< 100 bpm) music. The excerpts used need only be very short (< 1 s) for the listener to identify emotional content in a piece (Bigand, Filipic et al., 2005), but it is acknowledged herein that in order to retain some degree of ecological validity for tennis, and for the emotional response to develop significantly (cf. Koelsch et al., 2006), excerpts longer than 1 s are appropriate. There are also other quasi-structural musical concepts such as syncopation (displacement of the regular metrical accent in music typically caused by stressing the weak beat or stressing notes that are not on the beat at all), which may violate the listener's musical expectations, thereby inducing shifts in emotional state (Sloboda, 1991, 1992). These will be kept to a minimum in the present study, by selecting a track with a comparatively predictable structure, in order to isolate the variables of tempo and intensity most effectively.

The question of whether to use researcher-selected or participant-selected music has been a constant thorn in music researchers' sides (Karageorghis & Terry, 1997), primarily because the extrinsic sources of musically-induced emotion are inherently idiosyncratic (Sloboda & Juslin, 2001). Self-selected music with emotive associations appears to be a potent means by which emotions can be induced (Rickard, 2004), and this effect appears to have application in sport (Pates et al., 2003). Cultural exposure can affect music preferences for music selections (Peretz & Gaudreau, 1998); the resultant familiarity can improve vigilance performance (Fontaine & Schwalm, 1979), and polarise emotional responses to both positive and negative music, as measured by affective and facial EMG data (Witvliet & Vrana, 2007). Because of the apparent interaction of intrinsic qualities and extrinsic variables such as acculturation (Balkwill & Thompson, 1999), and the exaggerated emotional response that may be associated with overfamiliarity (Witvliet & Vrana, 2007), the track used in the present study will be one that is likely to be familiar to participants, yet is relatively unacculturated.

To retain continuity with the preceding study, the Affect Grid (Russell, Weiss et al., 1989) will be used as a measure of affective response to the music. Russell, Weiss et al. established the reliability and validity of this measure in relation to Russell’s (1980) original circumplex model. The two orthogonal dimensions of pleasure and arousal appear to be reliable predictors of emotional experiences with music (North & Hargreaves, 1997; Ritossa & Rickard, 2004); a finding which has been replicated in cardiorespiratory data (Nyklícek et al., 1997). However, recent evidence suggests that the circumplex model may lack specificity when used in isolation to gauge the emotions expressed in music: People can say, with great precision, how emotions relate to short unfamiliar instrumental selections. They can do so rapidly, with significant reliability, and can even identify subtle variations in emotion content which are not readily encompassed within the circumplex model (Collier, 2007). Therefore, although musically-*induced* emotions were of interest in the present study, it was decided to use a further qualitative measure of affective experience to provide some qualitative validation of the data obtained: The 28 descriptors originally used by Russell (1980) in his development of the affective circumplex model will be incorporated. Nonetheless, it should be noted that the present protocol was targeted at identifying the emotions *induced in the listener*, as opposed to the emotions expressed by the music – the latter approach being the more common in previous musicological research (e.g., North & Hargreaves, 1997; Ritossa & Rickard, 2004).

Gray (1994) described the existence of three brain systems involved in emotion behaviours: One which responds to appetitive stimuli (behavioural approach/activation system, BAS), one involved in the fight-flight response to aversive stimuli (fight/flight system, FFS), and a third dealing with the inhibition of behaviour in response to aversive stimuli (behavioural inhibition system, BIS). Gray posited the idea of emotions as responses to positive or negative reinforcers, be they conditioned or unconditioned; a concept which has parallels with appraisal theories of emotion (e.g., Frijda, 1986) and for which neurophysiological pathways have since been described (e.g., Panksepp, 1998). Gray's three systems are represented in Figure 4.1. Both the BAS and BIS respond to conditioned or unconditioned *signals* of reward, punishment, non-reward, or non-punishment, to yield motoric and/or attentional responses conducive not only to survival, but also to sports performance. Music listening is an intrinsically rewarding activity (Menon & Levitin, 2005), and may serve as a conditioned signal to activate these systems to some degree.

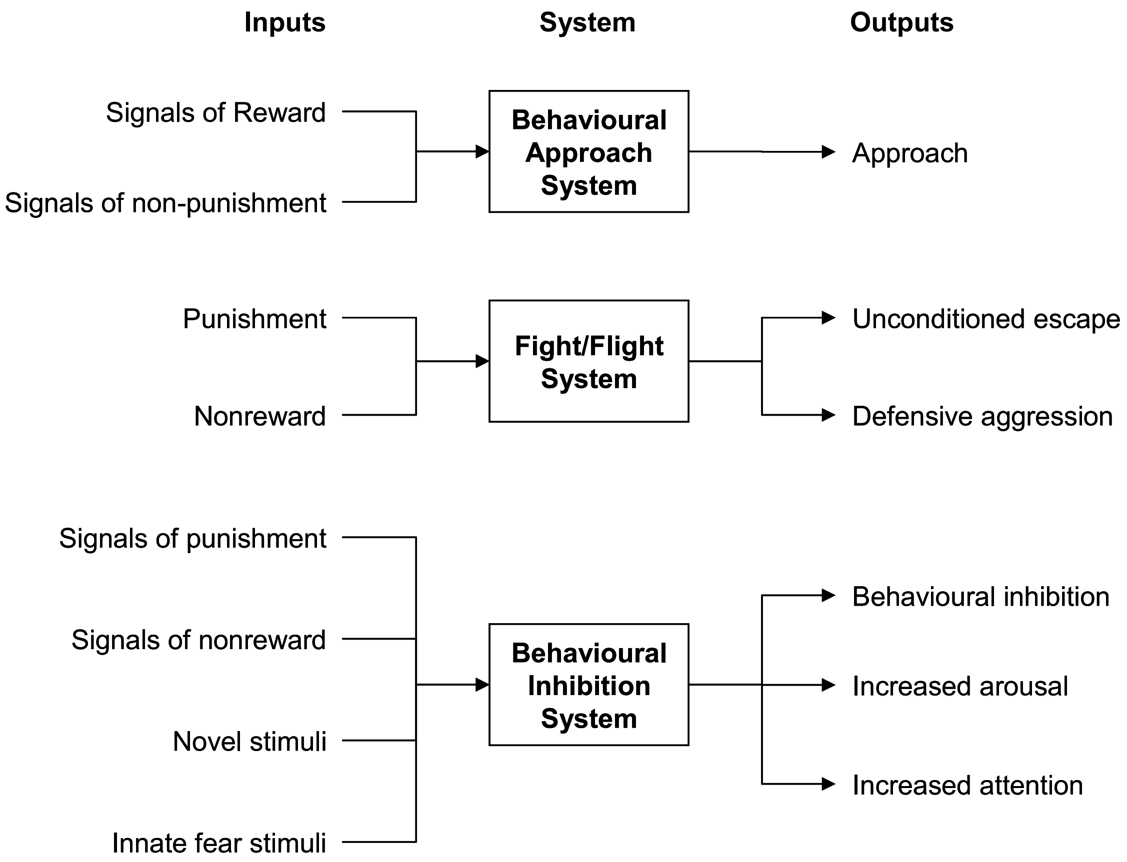

Figure 4.1. Gray's three fundamental emotion systems: Their inputs and outputs (adapted from Gray, 1994).

Based on the foregoing observations and assertions, we might expect that (conditioned or unconditioned) musically induced high-arousal utilitarian emotions (Scherer, 2004) of positive valence will prompt a phylogenetically prepared *approach*-type psychophysiological state that is designed to promote heightened activation (see Malmo, 1959) and action readiness (Frijda, 1986) in the organism. Such fundamental emotions, with clear approach or avoidance action tendencies, can consistently facilitate sport performance (Cerin, 2003). Indeed, evidence exists for the capacity of music to facilitate perceptual performance when played concurrently: Listening to unpredictable arousing music can enhance vigilance performance (Davenport, 1974), and this effect may be enhanced by faster tempi and higher intensities (North & Hargreaves, 1999). Music enhances reaction time performance (Bassagaoglu et al., 2004), and faster music tempi enhance visual attention processes (Amezcua et al., 2005). Nonetheless, the *residual* effects of musically-induced emotional responses on performance have yet to be elucidated.

4.3 Aim and Hypotheses

The principal aim of the present study is to intervene at the delivery stage of Bishop et al.'s (in press) model (see Figure 4.2), to examine the effects of manipulating music tempo and intensity on affective response and immediately subsequent CRT performance, while striving to retain a moderately high degree of ecological validity. This will be achieved in part by (a) using an experimental setup that simulated the return-of-serve scenario; (b) requesting that participants sat in a chair while listening via earbud-type earphones, typical of those commonly supplied with digital music players such as the iPod; and (c) obliging participants to perform the CRT task within 20 s of listening – the timeout allowed after resumption of play post-changeover. The following hypotheses are put forward:

H_1 Faster tempi and louder intensities will elicit higher subjective arousal as measured by the Affect Grid (Russell et al., 1989).

H_2 If degree of emotional arousal does indeed reflect the resources invested in an action tendency (J. F. Thayer & Faith, 2001), then this will elicit increased sympathetic response; and this will be evidenced in higher heart rates.

H_3 Faster tempi and louder intensities will be associated with approach-type action tendencies, manifested in shorter CRTs.

H_4 Faster tempi have been associated with higher valence (e.g., Webster & Weir, 2005); therefore, it is also predicted that faster tempi will elicit higher Affect Grid pleasantness ratings than slower tempi.

H_5 Music is also predicted to elicit higher pleasantness ratings than white noise, due to an aesthetic response that may be dependent upon its appropriateness to the listener (cf.

North & Hargreaves, 1996) or the listener's previous exposure to the track (cf. Peretz, Gaudreau, & Bonnel, 1998).

*H*₆ It is expected that ratings of subjective emotional arousal will be independent of those for pleasantness, and that this will be reflected in (a) low-to-zero correlation between each pair, and (b) selection of adjectives which describe both positive and negative affective states, irrespective of arousal level.

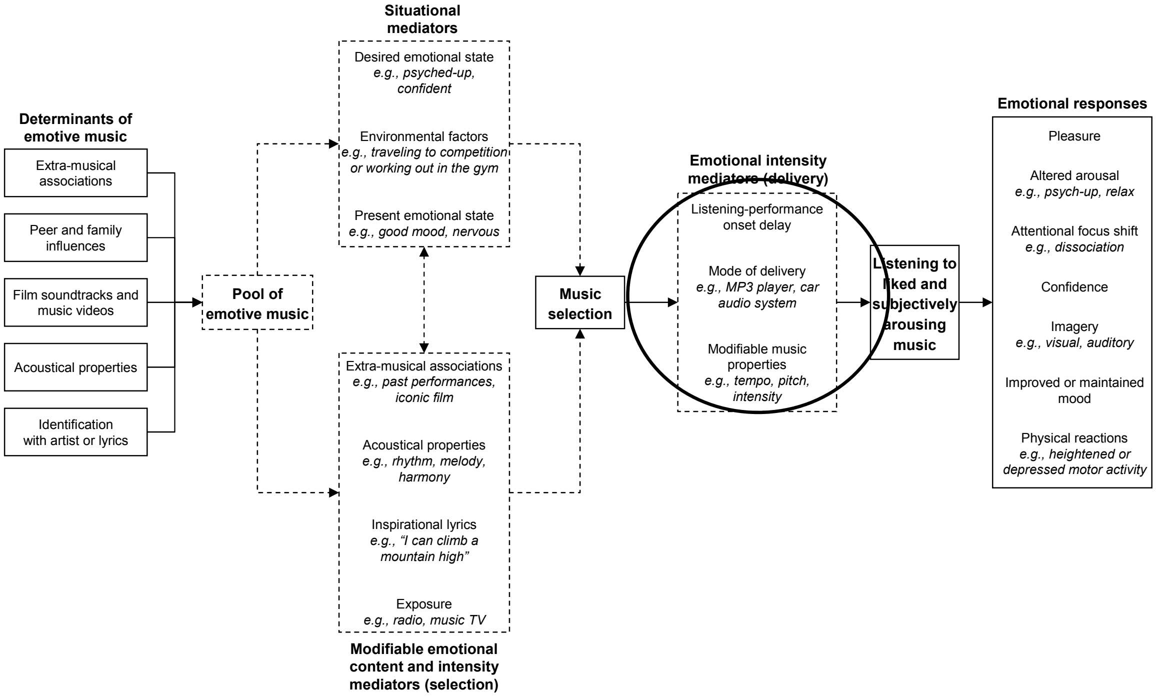

Figure 4.2. Stage of intervention for the present study (adapted from Figure 3.2).

4.4 Method

4.4.1 *Pilot Testing*

In order to estimate the sample size required for the main study, a convenience sample of ten volunteers (eight male, two female; mean age = 16.4 years, *SD* = 1.7 years) took part in a pilot study, to enable a priori sample size analysis. A repeated-measures design was employed, wherein all participants took part in all conditions. To investigate the efficacy of young tennis players' proclivity for selecting comparatively loud and fast music in order to psych-up (see Bishop et al., in press), choice reaction time (CRT) performance was compared for two conditions: (a) after 90 s of listening to a fast tempo (138 bpm) researcher-selected track played at an intensity of 75 dBA[1], and (b) after 90 s of relative quiet (background noise ≈ 40 dBA). Each participant completed both conditions twice in an A-B-B-A design; order of presentation of conditions was counterbalanced across participants (i.e., A-B-B-A, B-A-A-B, A-B-B-A for three consecutive participants). The intensity of 75 dBA was selected as a suitable level for the earbud-type earphones used, which contrasted markedly with the high participant-selected intensities in the first study (range = 84.7–115.9 dBA, mean intensity = 102.3 dBA, *SD* = 11.5 dBA). The decision to use a lower intensity was made because higher frequencies are not absorbed to such a great extent when listening via earphones – which can result in greater damage to the outer ear (The Health and Safety Executive, 2005); participants heard music in Study 1 via stereo loudspeakers located 1.2 m from the participant.

4.4.1.1 *CRT task*. Participants responded to visual stimuli displayed using the same setup used in the main study (see *Equipment and Materials* and *Procedures* subsections for full details of experimental protocol hereafter). However, there was one key difference: Participants registered their responses by stepping off-and-onto footpad switches located immediately under, to the side, and in front of their feet (see Appendix F for a photo of the setup). These pads were connected to an interface (Joybox; Sensory Software International, Malvern, UK), which outputted via Universal Serial Bus (USB 2.0 high speed) connection to a laptop computer.

4.4.1.2 *Determination of sample size for main study*. Power analysis software (GPower; Faul & Erdfelder, 1992) was used to determine a suitable sample size for the main

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[1] Sound intensity was measured using a digital sound meter (AZ 8928; AZ Instrument Corporation, Taichung City, Taiwan). This device was calibrated using a Brüel and Kjær (Nærum, Denmark) Sound Level Calibrator, type 4231.

study. Mean reaction times (silence mean = 250.86 ms; music mean = 225.28 ms) and the pooled standard deviation (28.65 ms) were entered into GPower's effect size calculation tool, to calculate Cohen's (1988) *d*; the returned value was .89. This was entered into GPower's sample size calculation tool, together with an alpha level of .05; a desired power of .9 was specified. A required sample size of 46 was returned by the software program.

4.4.2 *Participants*

An international junior tennis centre in southwest London, England, UK, catering to young tennis players from a wide variety of sociocultural backgrounds, was chosen as a suitable site for data collection. Participants volunteered to take part in the study, but were incentivised to take part with prizes (for 1st, 2nd, and 3rd places) as a part of an open-to-all reaction time competition within the tennis centre. The sample comprised 54 young tennis players, 33 male and 21 female; 54 participants were recruited to guard against participant dropout and deletions caused by multiple univariate and multivariate outliers. Participants' ages ranged from 13 to 22 years (*M* = 17.7, *SD* = 2.1 years). Twenty-seven participants trained full-time (20 or more hours of tennis per week); the remaining 27 were part-time. Thirty-six participants described their ethnicity as *White UK*; the remaining 18 participants comprised *Black African* (*n* = 1), *Black UK* (*n* = 1), *French* (*n* = 2), *Greek* (*n* = 1), *Greek Cypriot* (*n* = 2), *Lebanese* (*n* = 1), *Moldovan* (*n* = 1), *Slovakian*, (*n* = 1), *Sri Lankan UK* (*n* = 1), *Turkish* (*n* =1), *Ukrainian*, (*n* = 2), *White New Zealand* (*n* = 2), *White US* (*n* = 2). Participants' experience of competitive tennis ranged from 24 to 156 months (*M* = 84.8, *SD* = 34.1 months). Their LTA Ratings[2] ranged from 1.1 (world ranked player) to 9.2 (comparatively new to competitive tennis); the median rating was 4.2 (top and middle division county player), while the mode rating was 5.1 (lower division county player). Forty-

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[2] Please refer to the LTA website (www.lta.org.uk) for guidance on LTA Ratings.

nine participants were right-handed, five were left-handed. Participants' full demographic details can be found in Appendix Q.

4.4.3 *Equipment and Materials*

4.4.3.1 *Selection of auditory stimuli*. The music track selected was *Deepest Blue* by the artist *Deepest Blue*, which was sold under the *Data* record label (catalogue no. 55CDS). This track was selected because it satisfied a number of criteria: Its Official UK Charts (Official UK Charts Company, London, UK) Top 40 entry date of 2nd August 2003 (during the summer vacation period for all mainstream UK schools), its peak position of number seven in the charts, and its eight weeks spent in the Top 40 collectively meant that it was likely to be familiar to all participants; a quality which appears to be related to the degree of cultural exposure (North & Hargreaves, 1995).

4.4.3.2 *Modification of auditory stimuli*. Another important step in the selection of *Deepest Blue* was the capacity to alter the track's tempo using Time Scaling technology without the resultant versions appearing otherwise distorted in relation to the original. The track was recorded directly from a personal digital music player (Creative Zen Xtra 60GB, Creative Labs, Inc., Milpitas, California) via a 3.5 mm stereo plug-to-plug lead to a laptop computer (HP Pavilion zx5275, Hewlett Packard, Palo Alto, CA). Three music tempi were created using the digital music player's *Time Scaling* feature, to yield three recorded music template excerpts played at 99 bpm (slow tempo), 129 bpm (normal tempo), and 161 bpm (fast tempo). All three versions were played to nine peer reviewers for a qualitative assessment of their acoustical qualities. Each reviewer agreed that, while differences in tempo were clearly perceptible, the slower and faster versions did not appear otherwise different from the original.

All excerpts were cropped to 90 s in length, which reflected a considered methodological decision: To maintain excerpt length over actual lyrical/instrumental content.

This also enabled the participants to hear a portion of the verse and chorus. The three modified excerpts were copied for further editing; the three copies were opened in audio editing software (Ulead MediaStudio Pro Audio Editor 7.0, Ulead Systems, Inc., Taipei, Taiwan), and the intensity of each was increased to produce three new excerpts. The final moderate intensity stimuli were played at 55 dBA, whereas loud intensity stimuli were played at 75 dBA. Two digital white noise excerpts 90 s in duration were also created, one at each of the two intensities. A 90 s period of silence was also recorded, so that nine auditory stimuli conditions were created in total: Six music (three tempi x two intensities) conditions, two white noise conditions (two intensities), and one silence (control) condition (to enable the evaluation of music listening, per se, as a strategy).

4.4.3.3 *Presentation of auditory stimuli*. Auditory stimuli were delivered via a pair of earbud-type earphones (Creative EP-630, Creative Labs, Inc., Milpitas, California), which were plugged into a home stereo unit (Goodmans MS 355, Goodmans Industries Ltd., Portsmouth, UK); this step enabled amplification of the audio signal from the headphone socket of a laptop computer (HP Pavilion zx5275, Hewlett Packard, Palo Alto, CA). Presentation of all auditory stimuli was randomised.

4.4.3.4 *Measurement of affective and heart rate responses*. Participants recorded their affective responses to music by marking a cross in one box of a laminated version of the Affect Grid (Russell, Weiss et al., 1989), using a whiteboard marker. Participants also indicated their affective state by circling adjectives laid out in a grid formation on a laminated sheet (see Appendix H). There were 28 of these affective descriptors in total, identical to those used by Russell (1980). Participants' heart rate was monitored throughout using a chest strap-type heart rate monitor with infrared PC communication capabilities (Polar S610i; Polar Electro Oy, Kempele, Finland), at a 5 s sampling rate.

4.4.4 *CRT Task*

The study design was created and executed, and RT data recorded, using experiment generator software (E-Prime v.1.1.4.1; Psychology Software Tools, Inc., Pittsburgh, Pennsylvania, US). Visual stimuli (example in Figure 4.3) were presented using a computer projector (Hitachi CP-RS56; Hitachi Ltd., Tokyo, Japan) onto a white wall; the total projected image measured 1.29 m in width by 1.03 m in height, at a distance of 2.6 m from the participant. The image of the ball stimulus to which participants responded was projected onto the retina at a diameter of 0.99 mm, which corresponds to a tennis ball at a distance of 1.72 m away from the returning player (after the ball has landed, when the player is on or behind the baseline). The tennis court image backdrop represented the returning player's viewpoint when returning from the left-hand side (commonly referred to as the "Ad side") of the court. The ball stimulus could appear in one of three locations: Left (representing a serve out wide), centre (representing a serve to the body), or right (representing a serve along the centre service line).

Participants responded to visual stimuli with their dominant hand (i.e., the hand ordinarily used to hold the racket during match play) by striking one of three circular buttons[3] measuring 9 cm in diameter which were each affixed to one of three numeric keypads in such a way that each button operated a unique numeric key; each of keys 2, 5, and 8 corresponded to a correct response to a ball stimulus appearing on the left, centre, and right, respectively. The buttons were equidistantly spaced 0.58 m apart on a tabletop which stood 0.73 m from the floor; all buttons were located at a distance of 2.6 m from the projected image. Figure 4.4

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[3] This was chosen as a response mode after consultation with three UK National Level Coaches resident at the centre, who agreed unanimously that the movement required had greater ecological validity than the footpad response required in the pilot testing. There are no tennis-specific choice reaction time apparatuses available, as there are for karate (Roosen, Compton, & Szabo, 1999), for example.

displays the study setup. Participants were given one block of 24 trials in order to practise the task.

Figure 4.3. An example E-Prime visual stimulus.

Figure 4.4. Study setup.

4.4.5 *Procedure*

A repeated-measures design was employed wherein participants completed all conditions. The study was conducted in an internal air-conditioned and carpeted room with neither external walls nor opening windows. Thus, the room was relatively acoustically hermetic. After reading the Participant Information Sheet (see Appendix L), each participant was informed of what would be expected of them, and were invited to voice any remaining concerns. Once all questions had been answered to the participant’s satisfaction, and they had given their informed consent, fitting of the heart rate monitor was explained, and time allowed for the participant to fit the chest strap in private.

The participant sat in a chair at the beginning of the study, with the earphones in position. A projected image was presented which displayed the following instructions: *Please sit down in the chair and place the earphones in your ears. Breathe DEEPLY and slowly, and RELAX. Feel your arms and legs getting HEAVY. You feel CALM*. This screen was displayed for 45 s, after which a music excerpt was played for 90 s, accompanied by a blank screen. After 45 s had elapsed, the researcher prompted the participant to place a cross in a box of the Affect Grid (Russell, Weiss et al., 1989); the accompanying written instructions were as follows: *Please place a cross in ONE square to rate how you feel RIGHT NOW*. The researcher also prompted the participant to circle as many descriptors from the list of 28 words (cf. Russell, 1980) as they wished, to most accurately describe their affective state; the accompanying instructions for the descriptors read as follows: *Please circle any words from the following list that describe how you feel RIGHT NOW. You may feel NONE of them; this is fine*.

After the participant had listened to the excerpt and recorded their responses, a third screen appeared, displaying the following instructions: *Please remove the earphones, stand up, and get into a position to strike the reaction time buttons WITH YOUR DOMINANT HAND*. The participant then responded as quickly as possible to each of 24 trials (8 x 3 alternatives), which were presented in a software-generated randomised order. A screen depicting a blank court preceded each stimulus, for 1 s duration. Experimental stimuli moved on once a participant’s response had been registered, or after 1 s in the event of a movement error. During this period, the researcher logged the participant’s affective responses on the participant's study record sheet. After disappearance of the last of the 24 stimuli, the relaxation instructions reappeared. This procedure was repeated a further eight times, before the final instructions appeared, detailing the following: *Thank you; the study is finished. Please wait for further instructions*.

4.4.5.1 *Manipulation check*. Despite the use of contemporary technology to modify the tempi of the tracks without altering the pitch, this procedure can sometimes distort the characteristics of a track to such an extent that it is perceived by the listener as being a significant departure from the original. Although the modified versions of the selected track were submitted to eight peers for checking before proceeding with the main study, an additional manipulation check was undertaken with participants, to determine their subjective perceptions of the track's qualities. Specifically, the researcher asked the following question immediately after completion of data collection: "Did the slowed-down and sped-up versions of the track appear significantly different to the original version in any way other than the speed?" In addition, participants were asked, "Was the original version of the track you heard familiar to you prior to participating in this study?" in order to gauge the success of the selection strategy.

4.4.6 *Qualitative Data Analysis*

Adjective labels were entered into a spreadsheet software application (Microsoft Excel 2002, Microsoft Corporation, Fargo, ND, US), in separate categories based on their associated Affect Grid (Russell, Weiss et al., 1989) ratings – for both arousal and pleasantness dimensions independently. All occurrences of a descriptor in each category were entered into a *Find and Replace* search facility to quickly ascertain the number of each. Formulae were used to calculate the percentage occurrence of each descriptor for each rating on both arousal and pleasantness dimensions.

A content analysis (Weber, 1985) of selected descriptors was performed. On close inspection, it was decided that it would be parsimonious to cluster Affect Grid (Russell et al., 1989) ratings into three categories: *Low* (ratings 1-3), *moderate* (ratings 4-6), and *high* (ratings 7-9) – for both arousal and pleasantness. When entered into a three-by-three matrix, this arrangement gives nine new sections, eight of which are comparable to Larsen and Diener's (1992) suggested octants of the emotion circumplex model (*high activation*, *low activation*, *pleasant*, *unpleasant*, *activated pleasant*, *activated unpleasant*, *unactivated pleasant*, *unactivated unpleasant*); the final category (moderate arousal, moderate pleasantness) theoretically lies at the centre of the circumplex model. This arrangement afforded greater readability of the qualitative data. Mean Affect Grid (Russell, Weiss et al., 1989) ratings of each of the 28 descriptors were used to plot the position of each in two-dimensional space – pleasantness (abscissa) x arousal (ordinate), as per Russell's (1980) original conceptualisation of the affective circumplex model.

4.4.7 *Quantitative Data Analysis*

Reaction time data were imported into a software package which enables grouping of participants' individual E-Prime data (E-DataAid v.1.1.4.1; Psychology Software Tools, Inc., Pittsburgh, Pennsylvania, US). Participants' error rates during response to experimental stimuli were negligible (0.29%), and were automatically excluded from the analysis using E-DataAid's *Filter* option. Heart rate data were uploaded to heart rate monitor data management software (Polar Precision Performance SW; Polar Electro Oy, Kempele, Finland). Missing data points were accounted for by averaging of adjacent values (see Tabachnick & Fidell, 2006). CRT data, heart rate data, and Affect Grid (Russell, Weiss et al., 1989) data were transferred to a workbook in spreadsheet software (Microsoft Excel 2002; Microsoft Corporation, Fargo, ND, US), before transfer to statistical analysis software (SPSS 13.0 for Windows; SPSS Inc., Chicago, IL, US).

All data were screened for univariate outliers with z scores > ± 3.29, and for multivariate outliers using the Mahalanobis distance method, with $p < .001$; data were also checked for their suitability for parametric analysis. All dependent variable (DV) pairings were entered into correlation analyses, to assess the relative suitability of univariate or multivariate analyses; multiple analysis of variance (MANOVA) is best suited to either highly negatively or moderately correlated DVs, in either direction (Tabachnick & Fidell, 2006).

4.5 Results

4.5.1 *Qualitative Data Analysis*

Comprehensive content analysis (Weber, 1985) of descriptors is shown in Table 4.1 and Table 4.2. The order of descriptors, from top to bottom, is identical to that used by Russell (1980), and this ordering corresponds to a circular patterning in the circumplex model that begins and ends in the upper right quadrant of the model, progressing anticlockwise. Examination of the data reveals a relatively uniform distribution of both valence scores and arousal scores throughout the three post hoc groupings.

4.5.2 *Circumplex Structure of Affective Descriptors*

The affective descriptors selected by participants to describe their feeling state during each condition were located in two-dimensional space according to their mean Affect Grid (Russell, Weiss et al., 1989) ratings. It can be seen from visual inspection of Figure 4.5 that descriptors are arranged in a structure corresponding to that of Russell's (1980) original conceptualisation of the affective circumplex model.

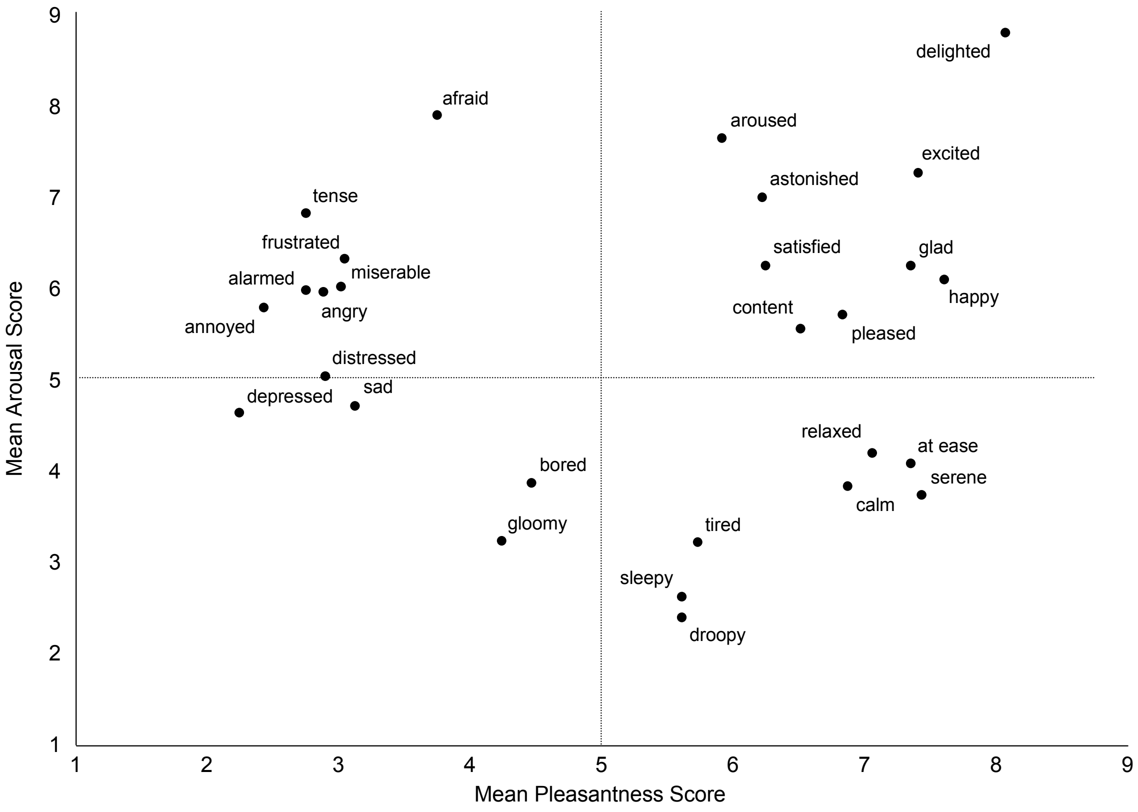

Figure 4.5. Affective descriptors arranged in two-dimensional space according to participants' mean Affect Grid (Russell, Weiss et al., 1989) ratings.

Table 4.1

Content Analysis of Descriptors Ascribed to Affect Grid (Russell, Weiss et al., 1989) Arousal Ratings

	Frequency (%) of occurrence		
Descriptor	Low arousal (ratings 1-3)	Moderate arousal (ratings 4-6)	High arousal (ratings 7-9)
Happy	18 (20.0%)	27 (30.0%)	45.0 (50.0%)
Delighted	0 (0.0%)	0 (0.0%)	6.0 (100.0%)
Excited	4 (4.3%)	16 (17.4%)	72.0 (78.3%)
Astonished	1 (16.7%)	0 (0.0%)	5.0 (83.3%)
Aroused	0 (0.0%)	7 (15.6%)	38.0 (84.4%)
Tense	2 (5.3%)	12 (31.6%)	24.0 (63.2%)
Alarmed	6 (15.4%)	14 (35.9%)	19.0 (48.7%)
Angry	4 (25.0%)	3 (18.8%)	9.0 (56.3%)
Afraid	0 (0.0%)	1 (9.1%)	10.0 (90.9%)
Annoyed	10 (12.5%)	38 (47.5%)	32.0 (40.0%)
Distressed	5 (29.4%)	7 (41.2%)	5.0 (29.4%)
Frustrated	2 (6.7%)	13 (43.3%)	15.0 (50.0%)
Miserable	1 (20.0%)	1 (20.0%)	3.0 (60.0%)
Sad	5 (55.6%)	1 (11.1%)	3.0 (33.3%)
Gloomy	20 (69.0%)	6 (20.7%)	3.0 (10.3%)
Depressed	10 (58.8%)	1 (5.9%)	6.0 (35.3%)
Bored	34 (50.0%)	24 (35.3%)	10.0 (14.7%)
Droopy	46 (90.2%)	5 (9.8%)	0.0 (0.0%)
Tired	37 (71.2%)	8 (15.4%)	7.0 (13.5%)
Sleepy	58 (86.6%)	9 (13.4%)	0.0 (0.0%)
Calm	62 (53.4%)	37 (31.9%)	17.0 (14.7%)
Relaxed	50 (45.0%)	41 (36.9%)	20.0 (18.0%)
Satisfied	2 (8.0%)	12 (48.0%)	11.0 (44.0%)
At ease	46 (46.0%)	39 (39.0%)	15.0 (15.0%)
Content	3 (11.5%)	14 (53.8%)	9.0 (34.6%)
Serene	10 (62.5%)	5 (31.3%)	1.0 (6.3%)
Glad	4 (19.0%)	4 (19.0%)	13.0 (61.9%)
Pleased	10 (20.0%)	20 (40.0%)	20.0 (40.0%)
% total responses:	32.2%	25.78%	42.00%

Table 4.2

Content Analysis of Descriptors Ascribed to Affect Grid (Russell, Weiss et al., 1989)

Pleasantness Ratings

	Frequency (%) of occurrence		
Descriptor	Low pleasantness (ratings 1-3)	Moderate pleasantness (ratings 4-6)	High pleasantness (ratings 7-9)
Happy	0 (0.0%)	17 (18.9%)	73.0 (81.1%)
Delighted	0 (0.0%)	0 (0.0%)	6.0 (100.0%)
Excited	2 (2.2%)	16 (17.4%)	74.0 (80.4%)
Astonished	2 (33.3%)	0 (0.0%)	4.0 (66.7%)
Aroused	9 (20.0%)	15 (33.3%)	21.0 (46.7%)
Tense	32 (84.2%)	2 (5.3%)	4.0 (10.5%)
Alarmed	30 (76.9%)	4 (10.3%)	5.0 (12.8%)
Angry	12 (75.0%)	4 (25.0%)	0.0 (0.0%)
Afraid	6 (54.5%)	3 (27.3%)	2.0 (18.2%)
Annoyed	66 (82.5%)	14 (17.5%)	0.0 (0.0%)
Distressed	13 (76.5%)	1 (5.9%)	3.0 (17.6%)
Frustrated	23 (76.7%)	3 (10.0%)	4.0 (13.3%)
Miserable	3 (60.0%)	1 (20.0%)	1.0 (20.0%)
Sad	5 (55.6%)	4 (44.4%)	0.0 (0.0%)
Gloomy	15 (51.7%)	7 (24.1%)	7.0 (24.1%)
Depressed	13 (76.5%)	4 (23.5%)	0.0 (0.0%)
Bored	24 (35.3%)	32 (47.1%)	12.0 (17.6%)
Droopy	9 (17.6%)	26 (51.0%)	16.0 (31.4%)
Tired	6 (11.5%)	30 (57.7%)	16.0 (30.8%)
Sleepy	11 (16.4%)	33 (49.3%)	23.0 (34.3%)
Calm	2 (1.7%)	42 (36.2%)	72.0 (62.1%)
Relaxed	7 (6.3%)	31 (27.9%)	73.0 (65.8%)
Satisfied	1 (4.0%)	14 (56.0%)	10.0 (40.0%)
At ease	3 (3.0%)	26 (26.0%)	71.0 (71.0%)
Content	3 (11.5%)	7 (26.9%)	16.0 (61.5%)
Serene	1 (6.3%)	3 (18.8%)	12.0 (75.0%)
Glad	2 (9.5%)	4 (19.0%)	15.0 (71.4%)
Pleased	3 (6.0%)	20 (40.0%)	27.0 (54.0%)
% total responses:	34.10%	26.38%	39.52%

4.5.3 *Quantitative Data Analysis*

4.5.3.1 *Outliers and normality*. Checks for outliers in each cell of the analysis revealed no univariate or multivariate outliers. Tests of the distribution of data in each analysis cell of the *Arousal score* data revealed violations of normality in five of the nine cells (all at $p < .05$; see Table 4.3): Arousal scores for the Fast-Loud Music and Fast-Moderate Music conditions exhibited significant negative skewness; arousal scores for the Slow-Loud Music, Slow-Moderate Music, and Silence conditions exhibited significant positive skewness. Tests of the distribution of data in each analysis cell of the *Pleasantness score* data revealed violations of normality in six of the nine cells (all at $p < .05$; see Table 4.3): Pleasantness scores for the Fast-Loud Music, Normal-Loud Music, and Silence conditions exhibited significant negative skewness; pleasantness scores for Loud White Noise and Moderate White Noise exhibited significant positive skewness; pleasantness scores for Slow-Moderate Music exhibited significant platykurtosis. Tests of the distribution of data in each analysis cell of the reaction time data revealed violations of normality in two of the nine cells (all at $p < .05$; see Table 4.3): Reaction time data for Normal-Moderate Music and Moderate White Noise conditions exhibited significant negative skewness. Heart rate data did not violate normality assumptions. Because violation of the analysis of variance (ANOVA) assumption of normality does not radically change the F value (Vincent, 2005), and because the violations were not due to outliers (Tabachnick & Fidell, 2006), the F test was still retained as the test of significance.

4.5.3.2 *Correlation analysis of DVs*. All dependent variable pairs were entered into a correlation analysis, to determine their interrelationships (see Table 4.4). Arousal and pleasantness were uncorrelated, $r(482) = -.07, p > .05$, which is comparable to Russell's (1980) original finding, in his second of three studies, of a correlation coefficient of 0.03. Thus, the ratings provided by participants for the pleasantness and arousal dimensions were orthogonal. Arousal score and reaction time exhibited a low correlation, $r(482) = -.14$, $p < .01$; all other DV pairs were uncorrelated.

4.5.4 *Main Effect of Condition*

Notwithstanding Tabachnick and Fidell's (2006) recommendations regarding DV interrelationships (p. 357), a repeated measures MANOVA was used for the preliminary analysis, in order to control for experimentwise error. Wilks' Lambda was chosen as the multivariate statistic to report, because of the comparatively large sample size, equal *N* values, and independence of all observations. The main effect of condition was significant, Wilks' Lambda, $F(32, 22) = 29.22$, $\eta_p^2 = .98$, $p < .001$. Follow-up univariate tests were conducted to examine differences between conditions for each of the four dependent variables: *Arousal score*, *pleasantness score*, *reaction time*, and *heart rate*. Mauchly's Test of Sphericity showed that the data for all dependent variables had violated the assumption of sphericity (see Table 4.5). Therefore, a Greenhouse-Geisser adjustment was applied to the data. Box's test of equality of covariance matrices could not be computed as there were fewer than two non-singular cell covariance matrices. Descriptive and univariate statistics are presented in Table 4.3, which indicates that three of the four dependent variables – *reaction time*, *arousal score*, and *pleasantness score* – gave rise to differences between the conditions.

Table 4.3

Descriptive Statistics and Univariate Statistics for all DVs

Dependent Variable	Condition	*M*	*SD*	Std. Skew.	Std. Kurt.
Reaction time (ms)	Fast-Loud Music	492.97	58.47	-0.37	-0.98
	Fast-Moderate Music	511.25	58.33	-0.10	1.16
	Normal-Loud Music	505.22	68.35	-0.93	-1.21
	Normal-Moderate Music	507.02	52.34	-2.03^{*}	0.37
	Slow-Loud Music	487.08	65.04	-0.57	-1.27
	Slow-Moderate Music	501.71	54.82	-0.96	-0.12
	Loud White Noise	498.02	59.31	-1.75	-0.51
	Moderate White Noise	510.50	49.34	-3.19^{**}	1.45
	Silence	505.91	63.01	-0.75	-1.29
$F(6.19, 328.22) = 2.34$, $\eta_p^2 = .04$, $p < .05$					
Arousal score	Fast-Loud Music	6.57	2.31	-2.08^{*}	-1.38
	Fast-Moderate Music	6.44	1.83	-2.14^{*}	-0.36
	Normal-Loud Music	5.56	2.20	-1.63	-0.98
	Normal-Moderate Music	5.09	2.02	-0.62	-1.39
	Slow-Loud Music	4.57	2.34	2.14^{*}	-1.08
	Slow-Moderate Music	3.26	1.94	3.07^{**}	0.90
	Loud White Noise	6.11	2.03	-0.61	-1.66
	Moderate White Noise	4.74	2.11	-0.79	-1.13
	Silence	2.94	1.92	3.13^{**}	0.75
$F(4.82, 255.37) = 24.06$, $\eta_p^2 = .31$, $p < .001$					

(*table continues*)

Table 4.3 (continued)

Dependent Variable	Condition	*M*	*SD*	Std. Skew.	Std. Kurt.
Pleasantness score	Fast-Loud Music	6.28	2.03	-2.59^{**}	0.60
	Fast-Moderate Music	6.89	1.83	-1.84	-0.90
	Normal-Loud Music	6.28	2.14	-2.31^{*}	-0.61
	Normal-Moderate Music	6.46	1.89	-0.62	-1.18
	Slow-Loud Music	5.43	2.51	-0.98	-1.64
	Slow-Moderate Music	5.85	2.09	0.03	-2.04^{*}
	Loud White Noise	2.91	2.62	3.79^{**}	0.00
	Moderate White Noise	3.52	2.46	3.11^{**}	-0.14
	Silence	7.13	1.95	-2.38^{*}	-0.75
$F(5.52, 292.58) = 29.36$, $\eta_p^2 = .36$, $p < .001$					
Heart rate (bpm)	Fast-Loud Music	86.56	12.95	0.58	-1.28
	Fast-Moderate Music	87.03	12.65	0.66	-1.54
	Normal-Loud Music	88.50	11.68	0.46	-1.53
	Normal-Moderate Music	86.06	12.09	0.12	-1.22
	Slow-Loud Music	87.61	12.25	-0.34	-1.11
	Slow-Moderate Music	87.88	12.69	0.00	-1.20
	Loud White Noise	87.07	11.04	-0.02	-0.65
	Moderate White Noise	86.90	12.52	0.25	-1.74
	Silence	87.01	12.57	-0.81	-1.32
$F(6.11, 323.94) = 1.36$, $\eta_p^2 = .03$, $p > .05$					

Note. Std. Skew. = standard skewness; Std. Kurt. = standard kurtosis.

* $p < .05$. ** $p < .01$.

Table 4.4

Bivariate Correlation Coefficients of Dependent Variables

	1	2	3	4
1. Arousal score	1.00			
2. Pleasantness score	-.07	1.00		
3. Reaction time	-.14*	-.06	1.00	
4. Heart rate	.02	-.09	.09	1.00
M	502.19	87.18	5.03	5.64
SD	59.07	12.20	2.41	2.57

* $p < .01$.

Table 4.5

Mauchly's Test of Sphericity – Main Effect of Condition

Dependent measure	Mauchly's *W*	χ^2	*df*	Greenhouse-Geisser epsilon
Reaction time	.242	71.141*	35	.774
Heart rate	.196	81.653*	35	.764
Arousal score	.081	125.816*	35	.602
Pleasantness score	.141	98.329*	35	.690

* $p < .001$.

4.5.4.3 *Post hoc tests*. Follow-up pairwise comparisons with Bonferroni adjustment indicated only one significant difference in CRT performance: Reaction time subsequent to listening to Fast-Loud Music (*M* = 492.97 ms, *SD* = 58.47 ms) was significantly lower than that after listening to Fast-Moderate Music (*M* = 511.25 ms, *SD* = 58.33 ms), *F*(6.19, 328.22) = 2.34, $\eta_p^2 = .04$, $p < .05$. Fast-Loud music also elicited significantly higher arousal ratings (*M* = 6.57, *SD* = 2.31) than Normal-Moderate music (*M* = 5.09, *SD* = 2.02), Slow-Loud music (*M* = 4.57, *SD* = 2.34), Slow-Moderate music (*M* = 3.26, *SD* = 1.94), Moderate White

Noise (*M* = 4.74, *SD* = 2.11), and Silence (*M* = 2.94, *SD* = 1.92), *F*(4.82, 255.37) = 24.06, η_p^2 = .31, *p* < .001. Silence (*M* = 2.94, *SD* = 1.92) elicited significantly lower arousal ratings than all conditions *F*(4.82, 255.37) = 24.06, η_p^2 = .31, *p* < .001, with the exception of Slow-Moderate music (*M* = 3.26, *SD* = 1.94), *p* > .05. Loud White Noise (*M* = 2.91, *SD* = 2.62) and Moderate White Noise (*M* = 3.52, *SD* = 2.46) were rated as significantly less pleasant than all other conditions, *F*(5.52, 292.58) = 29.36, η_p^2 = .36, *p* < .001. A full summary of all significant pairwise comparisons, together with associated 95% confidence intervals, is shown in Table 4.6. A comparison of mean arousal and pleasantness scores for all nine experimental conditions is depicted in Figure 4.6 below.

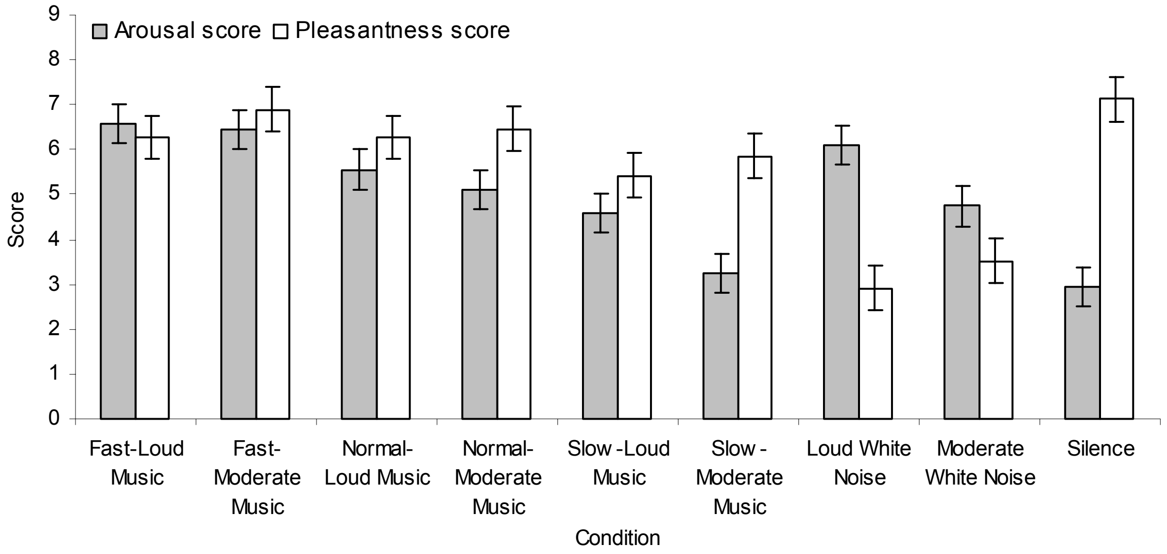

Figure 4.6. Mean arousal and pleasantness scores, by condition.

Table 4.6

Summary of Significant Pairwise Comparisons for All Conditions

Dependent variable	Condition 1	Condition 2	Mean diff. (1–2)	95% Confidence interval	
				Lower	Upper
RT (ms)	Fast-Loud Music	Fast-Mod. Music	-18.28*	-35.63	-0.92
Arousal	Fast-Loud Music	Normal-Mod. Music	1.48***	0.62	2.34
		Slow-Loud Music	2.00**	0.48	3.52
		Slow-Mod. Music	3.31***	1.94	4.69
		Mod. White Noise	1.83***	0.57	3.10
		Silence	3.63***	2.13	5.13
	Fast-Mod. Music	Normal-Mod. Music	1.35*	0.08	2.62
		Slow-Loud Music	1.87***	0.91	2.84
		Slow-Mod. Music	3.19***	2.03	4.34
		Mod. White Noise	1.70***	0.72	2.69
		Silence	3.50***	2.38	4.62
	Normal-Loud Music	Slow-Mod. Music	2.30***	0.92	3.67
		Silence	2.61***	1.22	4.00
	Normal-Mod. Music	Slow-Mod. Music	1.83***	0.67	2.99
		Silence	2.15***	0.84	3.45
	Slow-Loud Music	Slow-Mod. Music	1.31*	0.15	2.48
		Silence	1.63***	0.44	2.82

(table continues)

Table 4.6 (continued)

Dependent variable	Condition 1	Condition 2	Mean diff. (1–2)	95% Confidence interval	
				Lower	Upper
Arousal	Loud White Noise	Slow-Loud Music	1.54**	0.25	2.82
		Slow-Mod. Music	2.85***	1.34	4.36
		Mod. White Noise	1.37**	0.23	2.51
		Silence	3.17***	2.00	4.34
	Mod. White Noise	Silence	1.80***	0.64	2.95
Pleasant	Fast-Loud Music	Loud White Noise	3.37***	1.97	4.77
		Mod. White Noise	2.76***	1.36	4.16
	Fast-Mod. Music	Slow-Loud Music	1.46*	0.10	2.83
		Loud White Noise	3.98***	2.77	5.19
		Mod. White Noise	3.37***	2.00	4.74
	Normal-Loud Music	Loud White Noise	3.37***	2.23	4.51
		Mod. White Noise	2.76***	1.47	4.05
	Normal-Mod. Music	Loud White Noise	3.56***	2.13	4.98
		Mod. White Noise	2.94***	1.40	4.49
	Slow-Loud Music	Loud White Noise	2.52***	1.01	4.03
		Mod. White Noise	1.91**	0.36	3.45
	Slow-Mod. Music	Loud White Noise	2.94***	1.25	4.64
		Mod. White Noise	2.33***	0.92	3.75

(table continues)

Table 4.6 (continued)

Dependent variable	Condition 1	Condition 2	Mean diff. (1–2)	95% Confidence interval	
				Lower	Upper
Pleasant	Silence	Slow-Loud Music	1.70**	0.23	3.18
		Slow-Mod. Music	1.28*	0.04	2.52
		Loud White Noise	4.22***	2.65	5.80
		Mod. White Noise	3.61***	2.29	4.94

Note. Mean diff. (1–2) = Difference between means of Condition 1 and Condition 2; Lower = Lower boundary; Upper = Upper boundary; RT = Reaction time; Arousal = Arousal score; Pleasant = Pleasantness score; Mod. = Moderate.

* $p < .05$. ** $p < .01$. *** $p < .001$.

4.5.5 *Main Effects of Tempo and Intensity – Music Conditions Only*

A second repeated measures MANOVA was used in order to analyse the main effects of tempo and intensity for the music conditions only. There was a significant Tempo x Intensity interaction, Wilks' Lambda, $F(8, 46) = 2.40$, $\eta_p^2 = .29$, $p < .05$. The main effect of tempo was significant, Wilks' Lambda, $F(8, 46) = 16.53$, $\eta_p^2 = .74$, $p < .001$. The main effect of intensity was also significant, Wilks' Lambda, $F(4, 50) = 9.24$, $\eta_p^2 = .43$, $p < .001$. A series of repeated measures ANOVAs was conducted to examine differences between levels of the independent variables for each of the four dependent variables. Mauchly's Test of Sphericity indicated that all data satisfied the assumption of sphericity, with the exception of *arousal score* data for tempo, Mauchly's $W(2) = .87$, $\chi^2 = 7.54$, $p < .05$; and *reaction time* data for the Tempo x Intensity interaction, Mauchly's $W(2) = .85$, $\chi^2 = 8.44$, $p < .05$. Therefore, a Greenhouse-Geisser adjustment was applied to these data only. Box's test of equality of covariance matrices could not be computed as there were fewer than two non-singular cell covariance matrices. There was no significant Tempo x Intensity interaction, $p > .05$. There was a significant main effect of tempo for *arousal score*, $F(1.76, 93.40) = 40.50$, $\eta_p^2 = .43$, $p < .001$, and *pleasantness score*, $F(1.90, 100.90) = 10.03$, $\eta_p^2 = .16$, $p < .001$. There was a significant main effect for intensity, for *reaction time*, $F(1, 53) = 8.11$, $\eta_p^2 = .13$, $p < .01$, and *arousal score*, $F(1, 53) = 16.01$, $\eta_p^2 = .23$, $p < .001$.

4.5.5.1 *Post hoc tests*. Follow-up pairwise comparisons with Bonferroni adjustment indicated that fast tempo music ($M = 6.51$, $SD = 2.07$) elicited higher arousal scores than normal tempo music ($M = 5.32$, $SD = 2.11$), which, in turn, elicited higher subjective arousal than slow tempo music ($M = 3.92$, $SD = 2.14$). Fast tempo music ($M = 6.58$, $SD = 1.93$) elicited more positive valence than slow tempo music ($M = 5.64$, $SD = 2.30$); and normal tempo music ($M = 6.37$, $SD = 2.02$) elicited more positive valence than slow tempo music ($M = 5.64$, $SD = 2.30$). Figure 4.7 depicts mean arousal and pleasantness scores for all three music tempi. Loud intensity music ($M = 495.09$ ms, $SD = 63.95$ ms) elicited shorter reaction times than moderate intensity music ($M = 505.66$ ms, $SD = 55.16$ ms); and loud intensity music ($M = 5.57$, $SD = 2.28$) elicited higher subjective arousal than moderate intensity music ($M = 4.93$, $SD = 1.93$). The relationship between reaction time and arousal score for both

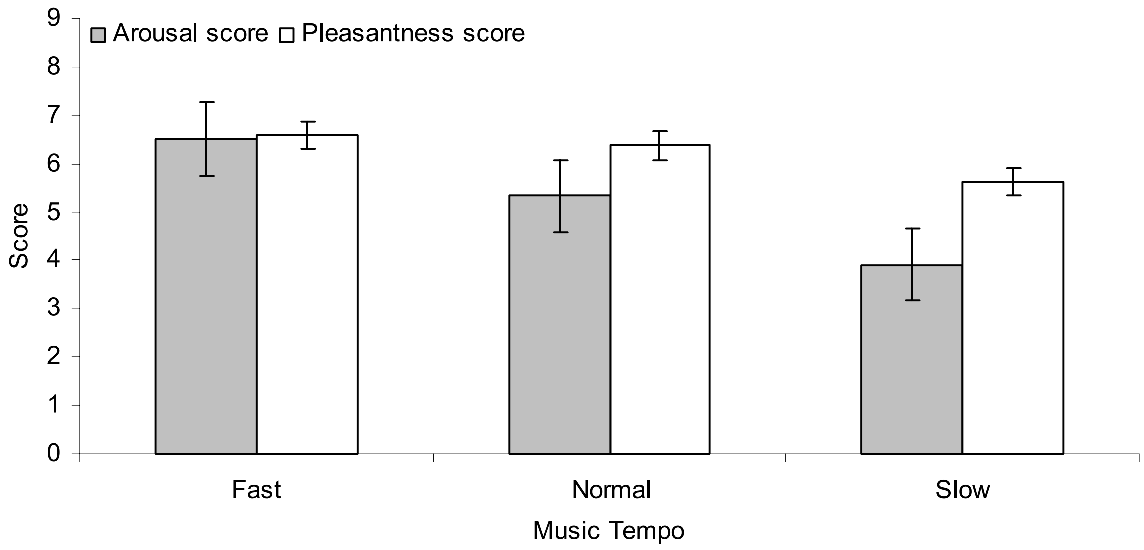

Figure 4.7. Mean arousal and pleasantness scores, by tempo.

music intensities is shown in Figure 4.8. All significant pairwise comparisons are presented in Table 4.7.

Table 4.7

Summary of Significant Pairwise Comparisons for Music Conditions Only

Factor	Dependent variable	IV level 1	IV level 2	Mean diff. (1–2)	95% Confidence interval	
					Lower	Upper
Tempo	Arousal	Fast	Normal	1.185**	.589	1.782
		Fast	Slow	2.593**	1.892	3.294
		Normal	Slow	1.407**	.584	2.231
	Pleasant	Fast	Slow	.944*	.346	1.543
		Normal	Slow	.731*	.239	1.224
Intensity	RT (ms)	Loud	Moderate	-11.570*	-19.717	-3.422
	Arousal	Loud	Moderate	.636**	.317	.955

Note. Mean diff. (1–2) = Difference between means of IV level 1 and IV level 2; Lower = Lower boundary; Upper = Upper boundary; RT = Reaction time; Arousal = Arousal score; Pleasant = Pleasantness score.

* $p < .01$. ** $p < .001$.

4.5.6 *Manipulation Check of Auditory Stimuli*

All participants replied that, aside from noticing that the slowed-down and speeded-up versions were slower and faster respectively, there were no perceived distortions. All participants recalled that they had previously heard the original version of the track.

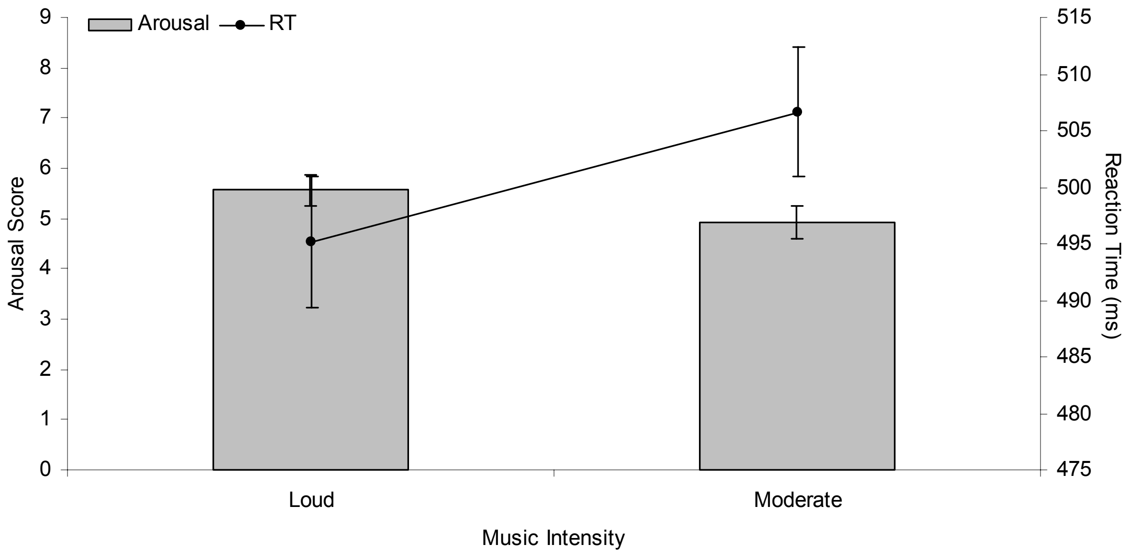

Figure 4.8. Mean RT and arousal scores, by intensity.

4.6 Discussion and Conclusions

4.6.1 *Overview*

The primary aim of this study was to contrast the affective and behavioural consequences of listening to six varied musical excerpts (3 tempi x 2 intensities) of a single researcher-selected track, and to compare and contrast this in turn with the consequences of listening to (a) white noise played at two intensities and (b) a period of silence. There was mixed support for the experimental hypotheses. Faster tempi and loud intensity did elicit higher subjective arousal, and fast, loud music elicited the highest scores overall. However, there was no effect of condition on participants' heart rates. There was a significant effect of condition on CRT performance: Listening to music played at both a fast tempo and a high intensity yielded shorter RTs in a subsequent CRT task than did fast, moderate intensity music; on examination of music conditions only, louder intensities promoted shorter RTs. Faster tempi were associated with significantly higher valence/pleasantness, as were all music conditions and silence when contrasted with white noise. Evidence was also produced for the independence of the two circumplex model dimensions: The two were highly uncorrelated ($r = -.07$), and concomitant descriptors frequently associated ($\geq$ 50% of total usage) with *high* *arousal* included *afraid*, *angry*, *aroused*, *astonished*, *delighted*, *excited*, *frustrated*, *glad*, *happy*, *miserable*, and *tense*.

4.6.2 *The Contribution of Tempo to Emotional Responses*

Extant evidence suggests that tempo is a strong determinant of affective responses to music (Webster & Weir, 2005), having been instilled in early childhood (Dalla Bella et al., 2001). The findings of the present study add to this body of evidence; music excerpts played at both fast and normal tempi were considered significantly more pleasant than music played at a slow tempo. One possible explanation for such observations is that faster tempi are *iconically representative* (Scherer & Zentner, 2001) of high energetic arousal (R. E. Thayer, 1989), a desirable state for all living organisms which implies health and vitality; its polar opposite – low energetic arousal – is indicative of undesirable psychophysiological states such as depression, illness, and even being on the verge of death.

Faster tempi did not elicit shorter RTs, despite the fact that faster tempi were also associated with higher arousal – which was slightly negatively correlated with RT. When taking into consideration the aforementioned association of faster tempi with pleasure, this may be reconciled in terms of appraisal theory: *Avoidance* action tendencies (Frijda, 1986) are closely related to stimuli that are perceived as a threat to the organism. Music that is considered both highly unpleasant and potentially dangerous (e.g., very loud and highly disliked music) may lead to an avoidance-type psychophysiological preparatory response, but highly liked and arousing music should not elicit such a response. This can also be explained in terms of Gray's (1994) fight-flight system, in which resources are mobilised for either unconditioned escape or defensive aggression (see Figure 4.1), both of which would necessitate increased motor activity. More pleasant emotions may lead to activation of the Behavioural Approach System (BAS) – yielding *approach* action tendencies – which may not stem from such primal survival-oriented neural pathways. Nonetheless, this kind of auditory stimulus may bring about such approach or exploratory behaviour, which includes increased attentiveness to/interest in the environment, and forward locomotion; both responses could viably produce faster CRT performance – either in isolation or conjointly.

4.6.3 *The Predictive Value of the Circumplex and Qualitative Affective Data*

The affective circumplex model has heuristic value, because it suggests a clear structure for the effects that emotions can have on behaviour (Larsen & Diener, 1992). J. F. Thayer and Faith (2001) suggested that valence represents the evaluative outcome necessary to initiate an approach or withdrawal response (cf. Zentner & Kagan, 1996), whilst arousal reflects the resource investment in the action tendency (cf. Frijda, 1987). This notion is somewhat supported by Frijda et al.'s (1992) assertion that "It is intensity more than anything else that determines whether emotions lead to socially consequential behaviour" (p. 62). However, Larsen and Diener noted that the circumplex model does not account for different action tendencies, or *action readiness*, which Frijda, Kuipers, and ter Schure (1989) described as "…what links experience and behavior…a reflection of the actual state of behavioural readiness" (p. 213). According to Frijda et al.'s (1989) delineations, anger and fear – which are both located in adjacent circumplex space – have differing action readiness modes associated with them (moving against vs. moving away, respectively).

The present results appear to support both Larsen and Diener's (1992) and J. F. Thayer and Faith's (2001) contentions. Emotional responses to music which encompassed high arousal, independently of positive or negative valence, were related to shorter RTs. Given that arousal was slightly negatively correlated with RT, and that valence exhibited almost zero correlation, we might expect that descriptors most suited to CRT performance improvement would fall in the region of high arousal (scores ≥ 7), irrespective of their valence (pleasantness). Examination of Figure 4.5 reveals that five affective descriptors were located within this region (from left to right): *Afraid*, *aroused*, *astonished*, *excited*, and *delighted*. These words may therefore be suitable for intervention checks in the field, when ascertaining the efficacy of strategies implemented to improve athletes' reaction time performance, whether they incorporate music or not.

The summary rows of Table 4.1 and Table 4.2 show that participants' valence and arousal ratings were fairly evenly distributed across the descriptors, with only a slight polarisation of each, which is what we might expect if the mean ratings depicted in Figure 4.5 are to mirror the circular structure of the original circumplex model (Russell, 1980). However, there is a notable dearth of adjectives occupying the sector representing moderate pleasantness (scores 4-6) and high arousal (scores ≥ 7); only *aroused* falls within these confines. Previous discussions of basic emotions tend towards agreement – implicitly or otherwise – that these fundamental emotions possess some degree of positive or negative valence (e.g., Ekman, 1999; Izard, 1992; Oatley & Johnson-Laird, 1987; Ortony & Turner, 1990); indeed, it is pivotal to Russell's (2005) concept of *core affect*. The notion of valence has understandable implications for the organism's wellbeing and is also, therefore, a key consideration in the appraisal of an emotive event (cf. Lazarus & Folkman, 1984). This observation may reflect the fact that approach (positive valence) or withdrawal (negative valence) responses are clear-cut, whereas the investment in the action tendency (J. F. Thayer & Faith, 2001) is reflected by fluctuating degrees of arousal, which is mediated by a multitude of factors (R. E. Thayer, 1989). When considering the functionality of fundamental emotions in sport (Cerin, 2003), and the role of intensity in determining behaviour (Frijda et al., 1992), it is reasonable to consider that only emotions with implications for the organism (i.e., high or low in valence) are associated with high levels of arousal.

White noise was perceived as being significantly less pleasant than all other conditions, whether played at loud (*M* = 2.91) or moderate (*M* = 3.52) intensities; and loud white noise elicited the third-shortest mean reaction time (*M* = 498.02 ms). Adjectives associated with low valence (scores ≤ 3) were *depressed*, *annoyed*, *tense*, *alarmed*, *angry*, *distressed*, and *miserable*. Listening to such unpleasant yet arousing stimuli may trigger the Behavioural Inhibition System (Gray, 1994), which promotes a reduction in motor activity, but also concomitant increases in arousal and attention. Therefore, the comparatively short RTs witnessed may be due to enhanced attentional processes (perhaps mediated by increased output of the ascending reticular activating system) rather than increased motor activity; this requires further research to tease out the underlying mechanisms for the performance differences witnessed herein.

The increases in arousal witnessed herein may be further evidence for the role of this variable in potentiating the Mozart effect (Rauscher et al., 1993). Thompson et al (2001) found that participants improved their spatiotemporal performance after listening to an upbeat Mozart composition, when contrasted with that after listening to a slower and sadder Albinoni piece. Concurrent measures of mood and arousal showed that high subjective arousal and increased high-energy mood (cf. R. E. Thayer, 1989) both led to significantly improved performance. The similarity between the acoustical characteristics of the pieces used by Thompson et al. and the variants employed in the present study are worthy of attention: Music exhibiting faster tempi appeared to elicit higher arousal in both studies, which was, in turn, reliably associated with superior visuospatial performance, albeit in qualitatively different tasks.

4.6.4 *Potential Limitations and Recommendations for Future Research*

The excerpt used in the present study was somewhat repetitive in nature, being a mainstream dance music track with few vocals. However, this was believed to moderate the subjective complexity of the track, which North and Hargreaves (1995) demonstrated shows an inverted-U relationship with liking. Elements of uncertainty in music appear to enhance the emotional impact on the listener (Meyer, 1956), and this variability can improve vigilance performance (Davenport, 1974). The excerpt in the present study was also played for a total of six occasions, in its various forms, which might have rendered later performances very predictable indeed. However, this potential confound was addressed to some extent, through randomisation of conditions.

A number of extra-musical factors mediate the emotional response to music, not least of which are features of the listening environment (Saarikallio & Erkkilä, 2007; Scherer & Zentner, 2001). Music has the power to modify the affective response to the visual environment (Baumgartner, Esslen et al., 2006; Eifert et al., 1988), and this may be mediated through activation of emotion processing areas of the brain. Baumgartner, Lutz et al. (2006) combined fearful, happy, and sad pictures from the International Affective Picture System either alone or in combination with congruent emotive classical music. The combined conditions elicited far greater activation in limbic and paralimbic structures, most notably in the amygdala, hippocampus, and parahippocampal region; participants concomitantly rated the happy conditions as significantly more positive, and the fear and sad conditions as more negative. Therefore, it was considered important in the present study to create a visually sterile environment to guard against any potential interaction effect. This was achieved to a large extent by presenting the visual stimuli against a white projector screen, the surround to which was a plain wall; the participant sat with their back to the only window in the room (see Figure 4.4).

Faster tempi were associated with higher arousal scores in the present study; and higher arousal was significantly negatively correlated with RT. Research into the effects of music listening on reaction time performance has identified underlying neural activity. Amezcua et al. (2005) examined the effects of fast and slow music tempi on selective attention, using event-related potentials (ERPs) as an index of target detection in a computer screen oddball paradigm. They found that listening to faster tempo music led to a significantly reduced latency of the P300 ERP, whose activation time-course in the scalp has been related to activation in anterior cingulate (an interface of emotion and cognition) and precuneus (an area of sensorimotor integration implicated in spatial attention) (Mulert et al., 2004). Amezcua et al.'s findings suggest that the resultant RT performance was improved as a result of enhanced stimulus detection. Thus, although the connection between faster tempi and RTs in the present study is somewhat tenuous, further neurophysiological investigation may yield activation in visuomotor areas, mediated by emotion-processing areas, as a result of listening to faster tempo music.

The impact of personality traits such as introversion/extraversion on musically-induced emotions were not accounted for in the present study, despite the fact that researchers have suggested that emotional responses may be mediated by such traits (Kallinen & Ravaja, 2004). Geen et al. (1985) asked participants previously classified as introverts or extraverts to perform a vigilance task in the presence of auditory noise. Introverts demonstrated improved detection at an intensity of 65 dB, whilst extraverts performed better at 85 dB. Kallinen and Ravaja (2004) found that high BIS sensitivity and low BAS-FS (fun-seeking) scorers, as measured by the BIS/BAS scales (Carver & White, 1994), exhibited greater overall alpha activation as a result of listening to music, suggesting greater levels of general arousal. To improve upon the present design in future studies, it may be prudent to employ some measures of personality, in order to gauge the contribution of these trait-like states on individuals' responsiveness to music.

Participants in the previous study of the present research programme were frequently in a negative mood when choosing to listen to music, supporting previous findings, that music is often used to up-regulate mood (Saarikallio & Erkkilä, 2007; R. E. Thayer et al., 1994). Given that one possible mechanism of emotional induction as a consequence of music listening is via facilitation of pre-existing emotions (Scherer & Zentner, 2001), some assessment of participants' existing emotional state may inform subsequent data interpretation. However, this was not done in the present study. But given the comparative proximity of consecutive conditions in the present study protocol, it is plausible that each preceding condition constituted the *present emotional state* (Bishop et al., in press). The potential impact of pre-existing emotional state was thereby accounted for by randomisation of conditions.

Heart rate data in the present study were not particularly informative, which stands in contrast to cardiorespiratory data from previous studies, which have shown psychophysiological indices to be fairly representative of emotional responses to music (Kallinen & Ravaja, 2004; Krumhansl, 1997; Nyklícek et al., 1997) and of basic emotions generally (Rainville et al., 2006). However, these studies have used considerably more sophisticated methods, such as measures of heart rate variability (HRV), which provides a more accurate and detailed index of autonomic responding. The 5-second sampling rate was unsuitable to detect subtle shifts in cardiac rhythm, such as is possible using HRV measures. Future studies should seek to use HRV as a dependent measure in conjunction with affective and behavioural data, to ascertain the degree to which sympathetic and parasympathetic nervous systems are involved in mediating the affective and behavioural changes witnessed in the present study.

Neurophysiological research of emotional responses to music is still very much in its infancy, but a fruitful next step in the research process would be the acquisition of neurophysiological data (e.g., using fMRI), in order to develop a better understanding of the neural mechanisms underlying the affective and behavioural changes observed herein. It is not clear whether the observed differences in performance were as a result of improved perception, more efficient or forceful movement patterns, or a combination of these. An exploratory whole-brain analysis of activations during music listening and subsequent CRT task performance will inform the use of music in sporting contexts to a greater extent.

4.6.5 *Summary*

The sources of emotion in music are manifold, and can be broadly delineated into intrinsic and extrinsic categories. Although extrinsic sources have been more frequently identified as contributing to young tennis players' personally emotive music (Bishop et al., in press), and are evidently potent elicitors of emotion (Rickard, 2004), they are also essentially individual in nature. Therefore, the present study focused on two intrinsic sources of emotion, tempo and intensity; two music properties which are easily manipulable for any consumer, thanks to contemporary technology. Present data showed that music played at both fast tempi and loud intensities can not only increase the intensity and valence of the emotional response to music, but that this response also improves subsequent reactive performance.

CHAPTER 5: NEUROPHYSIOLOGICAL INDICES OF EMOTIONAL RESPONSES TO MUSIC LISTENING AND SUBSEQUENT CHOICE REACTION TIME PERFORMANCE

5.1 Introduction

The neural correlates of affective experiences have become increasingly well mapped, and *affective neuroscience* has consequently become a discipline in its own right, stemming from the pioneering work of LeDoux (1996), Panksepp (1998), and Damasio (2000). Emotions are evolutionarily adaptive in their inception, and operate throughout all levels of the nervous system (Schulkin et al., 2003). Indeed, Hagemann et al. (2003) observed that emotions may be described as

> …an *organismic response* to an environmental event that facilitates the rapid *mobilization for action*. This response involves *multiple systems* of the organism, such as cognitive, behavioural, and autonomic sub-systems. When these response systems are efficiently coordinated, they allow for *goal-directed behavior* in the service of flexible *adaptation* of the organism to changing environmental demands. (p. 80)

Activation of Gray’s (1994) behavioural approach system (BAS) was posited as an underlying mechanism for the performance changes witnessed in the previous chapter. The BAS is a neural system attuned to rewarding or incentive-based stimuli. When appropriately triggered, the organism will experience positive feelings and exhibit *approach* behaviour. Panksepp (1998) describes the same neural axis as an appetitive motivational, or SEEKING, system which underlies the behaviours of an organism exploring its environment in order to gain the fruits therein, “...from nuts to knowledge, so to speak” (p. 145). According to Panksepp, central to the key neural circuitry of this system is the lateral hypothalamus, which responds both to homeostatic imbalances, and to environmental cues that may signal the promotion or cessation of such imbalances. Such external cues may be strong, with biological relevance for the organism (e.g., a food source), or may simply be comparatively weak cues that have come to be associated with the stronger ones (e.g., footprints left by the food source); for example, through long-term potentiation (Bliss & Lomo, 1973).

Despite the fact that music has no obvious inherent survival value, music emotion research has blossomed within the past decade, perhaps due to the ease with which the researcher is able to rapidly – and precisely – manipulate the listener's emotions through musical stimuli. Blood et al. (1999) used positron emission tomography (PET) to examine the neural response to six musical stimuli of varying dissonance (disharmony), and found that activation of parahippocampal gyrus and precuneus correlated positively with increasing dissonance; orbitofrontal cortex, subcallosal cingulate cortex and frontal pole activity exhibited negative correlations, implying a role for these latter areas in the processing of positive emotions.

Blood and Zatorre (2001) used *chills* (cf. Goldstein, 1980) as a psychophysiological index of participants' strong emotional responses to a self-selected piece of music, and observed correlations with activity in both emotion-processing structures (e.g., anterior cingulate, orbitofrontal cortex, insula) and areas associated with motor processes (supplementary motor area and cerebellum). The effect of listening to the self-selected music was contrasted with control music, which comprised the tracks selected by other participants (each control track was used once only). They observed decreases in activity of the cuneus (occipital cortex containing primary [striate] visual cortex and extrastriate cortex) and precuneus (parietal cortex involved in many aspects of sensorimotor functioning) as a result of listening to self-selected music, which may suggest that attention to external visual stimuli was somewhat reduced. This might have been a function of a tendency to focus inwardly when listening to self-selected rewarding music; the precuneus subserves a number of processes, including heightened self-awareness (Cavanna & Trimble, 2006).

Similar emotional responses have also been observed in unfamiliar music. Brown et al. (2004) played participants excerpts of unfamiliar instrumental music, and observed activation in many limbic and paralimbic structures, including subcallosal cingulate gyrus, hippocampus, and the nucleus accumbens. This may be due to the fact that specific regions of the brain are devoted to the identification of emotion, inherent in the structural characteristics of the music: Khalfa, Schon, Anton, and Liegeois-Chauvel (2005) manipulated the emotional valence of music excerpts by altering tempo and mode. They found that, despite activation of dorsolateral prefrontal cortex by both sad and happy music, sad excerpts elicited stronger activation in left orbitofrontal cortex and mid-dorsolateral frontal cortex.

Parahippocampal cortex appears to be a region of the brain important for processing unpleasant auditory stimuli (Blood et al., 1999; Koelsch et al., 2006), and damage to this area distorts emotional responses to such stimuli (Gosselin et al., 2006). The amygdala/medial temporal lobe is also a vital region for emotion recognition in music (Gosselin et al., 2007), although its primary role may be for the perception of danger (Gosselin et al., 2005). Conversely, pleasant musical stimuli consistently elicit stronger activation of the ventral striatum (Blood & Zatorre, 2001; Brown et al., 2004; Koelsch et al., 2006). Menon and Levitin (2005) used functional and effective connectivity analyses to demonstrate activation in a network of mesolimbic structures (nucleus accumbens, hypothalamus, insula, and ventral tegmental area) and the orbitofrontal cortex in response to music classified as *pleasant*. They postulated that dopamine-mediated connections existed between the affective and cognitive systems involved in listening to music. However, the authors also note the inability to conclude from their results whether the effects emanated from increased activation as a result of listening to pleasant music per se, or from reduced activation in the same structures as a result of listening to the unpleasant alternative (scrambled versions of the original excerpts).

Affective responses to music, especially with respect to valence, have been consistently mapped to neural structures integral to emotion-processing (e.g., Blood & Zatorre, 2001; Gosselin et al., 2007; Gosselin et al., 2006; Menon & Levitin, 2005). Given this fact, coupled with the evolving time course of such neurophysiological responses (Koelsch et al., 2006) and the impact of emotional responses to music upon ensuing motor (Bishop & Karageorghis, 2007) and cognitive (Schellenberg et al., 2007) performance, an exploration of the neurophysiological correlates of cognitive-motor performance during a musically-induced emotional state would represent a crucial step in the investigative process of the present research programme.

5.1.1 *Methodological Considerations*

Blood oxygenation level dependent (BOLD) fMRI detects local increases in relative blood oxygenation of areas of the brain, increases that are most likely a result of the action of neurotransmitters and reflect local neuron signals (Matthews & Jezzard, 2004). Therefore, by following basic principles of experimental design (Amaro Jr. & Barker, 2006), fMRI is a useful technique for pinpointing the neural correlates of participants' emotional responses to an external elicitor or during performance of a cognitive/motor task, throughout which the participant lies in an MRI scanner; although the act of providing in situ ratings of emotional stimuli may modify participants' responses (Hutcherson et al., 2005). Visual stimuli can be presented via either goggles or a projection screen (Engström, Ragnehed, & Lundberg, 2005).

Grey, Price, and Matthews (2000) suggested that anxiety resulting from being in the MRI scanner may confound any data obtained, but showed that this can be suitably reduced by using a familiarisation procedure which included advice on cognitive strategies for anxiety reduction, a tape-recorded demonstration of scanner noise, a visit to the control room before entering the scanner, a device to signal for adjustment of music volume, precise timings of each scan, and a clock visible during scanning. Grey et al.'s (2000) experimental participants displayed significantly less anxiety during and immediately after scanning, as measured by the STAI (Spielberger, 1983), when compared to controls.

The acoustic noise in an MRI scanner is considerable, reaching intensities of over 95 dB and frequencies of 1000-4000 Hz (Huettel, Song, & McCarthy, 2004). For this reason, participants in an MRI scanner should always wear protective earplugs and/or headphones. Despite the potentially harmful consequences of acoustic scanner noise, Boyle (2006) showed that the presence of such noise could significantly reduce perceptions of pain, when set at 85 dB; this effect was replicated with white noise.

There are many resources devoted to the procedures and pitfalls of analysing fMRI data, including online sources (e.g., Parry & Matthews, 2002), but Ramsey, Hoogduin and Jansma (2002) summarise the objectives of fMRI data analysis as follows: (a) to identify brain regions involved in the neural function of interest and/or to provide some quantification of the relationships between task characteristics, MR signal, and regions of the brain; and (b) to minimise residual noise in the data so as to maximise the likelihood of extracting function-related signal changes. SPM2 (http://www.fil.ion.ac.uk/spm) is one example of freeware available to researchers for the purpose of analysing fMRI data.

5.2 Rationale for the Present Study

Collectively, the first two studies of the present research programme elucidated the sources of emotion in young tennis players' personally emotive music, and then examined the impact of manipulating two intrinsic sources of emotion in music (tempo and intensity) on affective responses and ensuing choice reaction time (CRT) performance – arguably an index of the behavioural consequences of the musically-induced changes in affect. The present study was originated to identify neural mechanisms responsible for the affective and behavioural/performance changes observed in Chapter 4 data. Specifically, participants will undergo an almost identical procedure to that in the previous study, with the exception that both listening to music and subsequent CRT task performance will be performed during functional neuroimaging data acquisition in an MRI scanner. A sample of 15 volunteers will be recruited to this end; this sample size would permit extrapolation of findings from a fixed-effect model to over 80% of the population, with an experimental power of 1.0 (Friston, Holmes, & Worsley, 1999).

One important consideration in the recruitment of suitable participants may be the listener's degree of musical expertise. There are anatomical differences between the brains of musicians and non-musicians (Gaser & Schlaug, 2003); although this does not seem to alter their affective responses to music (Bigand, Vieillard et al., 2005; Waterman, 1996). There are also similarities across cultures in the perception of emotion in both familiar and unfamiliar cultural genres (Balkwill & Thompson, 1999; Morrison et al., 2003); and the ability to perceive emotion in music involves different neural pathways to those involved in perceiving the structural characteristics of music (Peretz, Gagnon et al., 1998). Degree of musical expertise does not appear likely to affect neurophysiological data in the present study, and so sampling will be undertaken irrespective of gender.

Despite affective data indicating that the listener can accurately identify the emotional content of a music excerpt within 1 s (Bigand, Filipic et al., 2005), neurophysiological evidence suggests that the emotional response to music unfolds over time (Blood & Zatorre, 2001; Krumhansl, 1997). Koelsch et al. (2006) played their participants excerpts of pleasant and unpleasant music approximately one minute in duration, and subsequently examined the difference between the participants' emotional responses to the first and second (30 s) halves of each excerpt. Although activations in identical structures (amygdala, hippocampus, parahippocampal gyrus, temporal poles, insula, and ventral striatum) were observed, the magnitude of the response was greater in the second block. Therefore, the retention of excerpts 90 s in length was considered apposite for the present study, in order to maximise the likelihood of observing activation in emotion-processing structures during the CRT task performance condition.

There appear to be some specific regions of the brain which process temporal structure and expectancies in music (e.g., Levitin & Menon, 2005; see Peretz & Zatorre, 2005). Although the perception of musical structure and the perception of emotion appear to be neuroanatomically separable, there is evidence to suggest that both mode and tempo are strongly indicative of emotional expression in music (Peretz, Gagnon et al., 1998; Webster & Weir, 2005), but the former appears to be a very strong index indeed, preceding the ability to emotionally categorise Western music (Filipic & Bigand, 2005). It can also determine the acoustic preferences of other primates (McDermott & Hauser, 2004). However, the ability to use mode as a predictor of emotional content may not be innate: Three to four year-olds cannot distinguish between emotions of tracks played in major and minor modes (Gregory & Worrall, 1996). The alteration of tempo therefore appears to be a valid means by which participant's emotional responses to music can be manipulated in the present study.

Previous neurophysiological investigation of emotional responses to music used stimuli which could be clearly delineated as pleasant or unpleasant. For example, music excerpts classified as *unpleasant* in Blood et al.'s (1999) and Menon and Levitin's (2005) work were jumbled versions of an original track. This is a suitable strategy for unequivocally identifying underlying neural structures involved in emotion-processing, but possesses low ecological validity for use in sporting contexts; listening to such concatenations is not a likely pre-performance listening strategy, nor is it likely to appear as background noise. Participants in Chapter 4 rated white noise at both intensities as less pleasant than all music conditions in the previous study, and it was considered to represent a closer approximation of the unwanted noise that a performer may be exposed to during training or competition. Also, mean pleasantness scores for all music stimuli in the previous study ranged from moderate to high.

For these reasons, white noise was retained as an unpleasant stimulus, in order to increase the likelihood of being able to differentiate between responses to pleasant and unpleasant stimuli.

5.3 Aim and Hypotheses

Behavioural and affective data from Chapter 4 showed that listening to fast loud music led to significantly greater subjective arousal, as measured by the Affect Grid (Russell, Weiss et al., 1989), and that this, in turn, yielded faster CRT task performance. Arousal appeared to be independent of the perceived pleasantness of the stimulus, although slower music was considered less pleasant than normal or fast tempo selections. Recent neurophysiological investigation of emotional responses to music has been confined to activations during music listening itself (Blood & Zatorre, 2001; Blood et al., 1999; Brown et al., 2004; Koelsch et al., 2006), despite evidence to suggest that music listening impacts on subsequent spatiotemporal performance (Rauscher et al., 1993). In order to provide a firmer argument for the use of music in the context of preparation for reactive tasks during sports performance, the aim of the present study is to perform an exploratory investigation of the possible neural mechanisms of not only the affective responses to music witnessed during listening in the previous chapter, but also of the ensuing behavioural responses observed during CRT task performance.

To this end, the following hypotheses were put forward:

H_1 In accordance with previous research which has demonstrated strong activation in Heschl’s gyrus – the location of much of the primary auditory cortex – in response to listening to music (Koelsch et al., 2006), it is proposed that music listening conditions will elicit significantly greater activations in primary auditory cortex than will a block of silence.

H_2 Since (a) increased activation of visuomotor areas appears to correlate with performance on reaction time tasks (Mohamed et al., 2004), and (b) higher music intensity was associated with faster CRT performance in the foregoing study, it is hypothesized that stimuli played at high intensities (whether music or white noise) will elicit greater activation in visuomotor pathways when compared to those played at moderate intensities.

H_3 Previous research suggests that highly emotionally arousing stimuli may decrease the attentional prerequisites for awareness (Anderson, 2005); and this may be brought about by the activation of evolutionarily-prepared appetitive or defensive motivational systems (Bradley et al., 2003). Therefore, it is anticipated that higher subjective arousal will also lead to greater activation of visuomotor areas, and to areas implicated in shifting visuospatial attention (e.g., precuneus; Cavanna & Trimble, 2006); these activations may be mediated by structures which have been previously identified in emotional responses to music (e.g., paralimbic structures; Blood et al., 1999).

H_4 Faster tempi have been associated with reduced latency in stimulus detection during performance of a reaction time task, as evidenced by electroencephalography (EEG; Amezcua et al., 2005); and were associated with higher valence and arousal ratings in Chapter 4. Therefore, it is expected that music played at fast tempo will elicit greater activation than will music played at slow tempo in (a) emotion-processing structures which have previously been observed to respond to rewarding stimuli (e.g., ventral striatum; Menon & Levitin, 2005), and (b) structures implicated in motivated attention (Bradley et al., 2003).

H_5 Based on the findings of previous studies (Blood & Zatorre, 2001; Blood et al., 1999; Brown et al., 2004; Koelsch et al., 2006; Menon & Levitin, 2005), it was expected that activity changes in limbic and paralimbic structures, explicitly, in the hippocampus, ventral striatum, and subcallosal cingulate cortices, would be observed in response to pleasant auditory stimuli. Because positive affect is associated with enhanced cognition (Ashby et al., 1999), it is proposed that listening to pleasant stimuli may result in greater activation of areas of frontal cortex previously implicated in executive function (e.g., medial frontal gyrus; Talati & Hirsch, 2005).

5.4 Method

5.4.1 *Participants*

An international junior tennis centre in southwest London, England, UK, catering to young tennis players from a wide variety of sociocultural backgrounds, was chosen as a suitable site for data collection. All participants were volunteers, and comprised 12 young tennis players, six male and six female. Participants' ages ranged from 18 to 28 years (*M* = 21.2 years, *SD* = 3.0 years). Participants were full-time tennis players whose experience of competitive tennis ranged from 60 to 168 months (*M* = 116.5, *SD* = 32.8 months). Nine participants described their ethnicity as *White UK*; the remaining three participants were *White French*, *South African*, and *Ukrainian*. Their LTA Ratings[1] ranged from 1.1 (world ranked player) to 5.1 (lower division county player); mode and median ratings were 2.2 (world ranked, national standard, and/or top division county player). All participants were right-handed, some of whom had participated in the previous study; their full demographic details can be found in Appendix R.

5.4.2 *Equipment and Materials*

5.4.2.1 *Auditory stimuli*. The music track used was *Deepest Blue* by the artist *Deepest Blue*, as in the previous study, electronically modified to yield six 90 s excerpts, as per the previous study (full details in Chapter 4, Section 4.4.3.1 and Section 4.4.3.2). Digital white noise, played at two intensities, and silence were also used as auditory stimuli, to create nine conditions.

5.4.2.2 *Auditory stimuli presentation*. Auditory stimuli were presented binaurally via an MRI-compatible auditory presentation system (MR Confon; Magdeburg, Germany), incorporating dynamic headphones (Confon HP-SI01; MR Confon, Magdeburg, Germany)

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[1] Please refer to the LTA website (www.lta.org.uk) for guidance on LTA Ratings.

with gradient noise-suppression properties (see Baumgart et al., 1998). Presentation of all auditory stimuli was randomised, using experiment generator software (E-Prime v.1.1.4.1; Psychology Software Tools, Inc., Pittsburgh, Pennsylvania, US).

5.4.2.3 *Visual stimuli presentation and responses*. Visual stimuli (for an example, see Figure 4.3) were presented via experiment generator software (E-Prime v.1.1.4.1; Psychology Software Tools, Inc., Pittsburgh, Pennsylvania, US), onto a screen at one end of the scanner bore. Participants viewed projected images using a mirror attached to the head coil (see Figure 5.1), and registered a response by pressing one of the three rightmost buttons on an MRI-compatible response box (LUMItouch™; Photon Control, Inc., Burnaby, B.C., Canada) with their right hand; the box was held in their left (non-dominant) hand.

5.4.3 *fMRI Data Acquisition*

Blood oxygen level-dependent images were acquired on a MAGNETOM Trio 3T MRI scanner (Siemens Medical Solutions; Bracknell, UK; see Figure 5.1) using Siemens' parallel imaging technology (iPat), which was deployed with a generalized autocalibrating partially parallel acquisitions (GRAPPA; Griswold et al., 2002) acceleration factor of two, via a Siemens eight-channel array head coil. In order to limit excessive head movements whilst ensuring the participant's comfort, the lateral spaces between the participant's head and the coil were padded with custom-built foam wedges. For each functional run, an ultra-fast echo planar gradient-echo imaging sequence sensitive to blood-oxygen-level dependent (BOLD) contrast was used to acquire 43 transverse slices (3 mm thickness) per TR (3000 ms, TE 31 ms, flip angle = 90°). Approximately[2] 505 volumes were acquired in a 192 mm x 192 mm field of view with a matrix size of 64 mm x 64 mm, giving an in-plane spatial resolution of 3 mm (generating 3 mm^3 voxels). Anatomical data were collected in the same orientation

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[2] Due to the variable length of the CRT task from one block to the next, the total number of volumes fluctuated slightly from participant to participant.

and plane as the functional data to enable localisation, using an MP-RAGE (Mugler & Brookeman, 1990) T1-weighted sequence, in which 176 one-mm slices alternated with a 0.5 mm gap. The structural sequence incorporated a 1830 ms TR, 4.43 ms TE, FoV 256 mm and a GRAPPA acceleration factor of two.

Figure 5.1. A participant being moved into the MAGNETOM Trio 3T MRI scanner.

5.4.4 *Experimental Design and Procedure*

Subsequent to thorough screening for suitability, the experimental procedure was explained to participants in full – both verbally and in written format (see Participant Information Sheet in Appendix M); participants gave their informed consent and were invited to raise any concerns before commencement of the study. A repeated-measures block design was employed, wherein participants completed all nine conditions. Each condition block consisted of a 45 s relaxation period, in which an auditory relaxation script was played (see Appendix I for the full script); 90 s of auditory stimulation; and a CRT task in which the participants were requested beforehand to respond as quickly as possible to each of 24 randomised stimuli (8 x 3 alternatives; participants were afforded one block of 24 practice trials prior to commencement of the study). A screen depicting a blank court preceded each stimulus, for 1 s duration. Experimental stimuli were changed once a participant's response had been registered, or after 1 s in the event of a movement error. After disappearance of the last of the 24 stimuli, the relaxation screen reappeared. This procedure was repeated a further eight times, before the final screen appeared, detailing the following: *Thank you; the study is finished. Please wait for further instructions*.

5.4.4.1 *Manipulation Check*. Despite the use of contemporary technology to modify the tempi of tracks without altering the pitch, this procedure can sometimes distort the sound of a track to such an extent that it is perceived by the listener as being a significant departure from the original. Although the modified versions of the selected track were submitted to peers for checking before proceeding with the main study, a manipulation check was undertaken with participants, to determine their subjective perceptions of the track's qualities. Specifically, the researcher asked the following question immediately after completion of data collection: "Did the slowed-down and sped-up versions of the track appear significantly different to the original version in any way other than the speed?" In addition, participants were asked, "Was the original version of the track you heard familiar to you prior to participating in this study?" in order to gauge the success of the selection strategy.

5.4.4.2 *Affect Grid (Russell, Weiss et al., 1989) ratings*. Participants recorded their affective responses to each auditory condition by marking a cross in one box of a laminated version of the Affect Grid (Russell, Weiss et al., 1989), using a whiteboard marker, after taking part in the neuroimaging study. This step was taken because the button box did not offer participants the opportunity to provide a response on a nine-point scale during scanning, nor would it allow for a single-item response such as that afforded by the Affect Grid. Conditions were subsequently grouped according to the arousal level and valence of the emotional responses elicited, to use as post hoc groupings.

5.4.5 *Image Preprocessing*

fMRI data were preprocessed using SPM2 (http://www.fil.ion.ac.uk/spm). Functional images were spatially realigned to the first image in the series to moderate the effects of participants' interscan head motion (Ashburner & Friston, 1997) (NB: Three participants' data sets displayed more than 2 mm translation and/or more than 2° rotation throughout acquisition, and were discarded accordingly; Appendix J depicts an extreme example). All functional images were then coregistered with the T1 image. Images were stereotactically normalised to the Montreal Neurological Institute ICBM-152 template[3] to account for neuroanatomical variability, and to facilitate reporting of activation sites according to standard space (Ashburner & Friston, 1997). Finally, data were smoothed using a Gaussian kernel of 7 mm full-width half-maximum (FWHM) to increase the signal-to-noise ratio according to the matched filter theorem[4].

5.4.6 *Data Analysis*

fMRI data were analysed using SPM2 (http://www.fil.ion.ac.uk/spm). The selected design matrix convolved the experimental design with a haemodynamic response function to model the haemodynamic lag behind the neuronal response. This model was estimated using proportional scaling over the session to remove global effects, and with a high pass filter of 128 s. Using a mean group contrast image, an exploratory first-level analysis was performed in order to estimate the fixed-effects of the experimental conditions upon the present sample, and to identify regions of interest (ROI). With a total of nine experimental conditions, many permutations of contrasts were possible. Five contrasts of acute interest were derived from both Chapter 4 data for entering into ROI analyses: *Music-silence*, *loud-moderate*, *fast-slow*, *high arousal-low arousal*, *high pleasantness-low pleasantness*. ROI analyses were performed

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[3] This template was generated by averaging 152 anatomical scans after correcting for overall brain size and orientation (Evans et al., 1993).

[4] This FWHM value was decided upon because it reflected a youngish sample, while still catering for some degree of anatomical variability between participants. It is acknowledged that spatial resolution is compromised as a result of such smoothing procedures.

using MarsBaR (Brett, Anton, Valabregue, & Poline, 2002), separately for each of the five contrasts. Because of the exploratory and novel nature of the present study, a decision was made not to determine ROIs from prior research, as these bore little relation to the present study. Therefore, 10 mm radius spherical ROIs were created using the mean coordinates of activations uncovered in the fixed-effects analyses; this ROI volume was preferred, because it affords a middle ground between sensitivity and accuracy. ROI contrast values for individual participants were then entered into a one-sample t test to enable identification of significant activations in all contrasts.

5.5 Results

5.5.1 *Affect Grid Ratings*

5.5.1.1 *Arousal*. All participants attributed Affect Grid (Russell, Weiss et al., 1989) ratings of 7 or higher on the *arousal* dimension to *fast loud music*, *fast moderate music*, *normal loud music*, *normal moderate music*, and *slow loud music*; therefore, all five conditions were labelled as conditions eliciting *high arousal*. Participants also unanimously attributed ratings of 3 or lower to the *silence* and *moderate white noise* and *slow moderate music* conditions; these were consequently labelled as eliciting *low arousal*. *Loud white noise* was unanimously rated as eliciting only *moderate arousal*.

5.5.1.2 *Pleasantness*. All participants attributed Affect Grid (Russell, Weiss et al., 1989) ratings of 7 or higher on the *pleasantness* dimension to *silence*, *moderate white noise*, *fast moderate music*, *normal moderate music*, and *slow moderate music*; therefore, all five conditions were labelled as conditions eliciting *high pleasantness*. Slow loud music and loud white noise were given ratings of 3 or less; these were labelled as eliciting *low pleasantness*. *Normal loud music* and *fast loud music* elicited feelings of only *moderate pleasantness*.

5.5.2 *First-level Analysis*

For the fMRI data, the *t*-maps (corrected for multiple comparisons) for music listening conditions and subsequent CRT task performance conditions displayed significant activations for five contrasts, which were guided by the experimental hypotheses stemming from Chapter 4. They were as follows: *Music-silence*, *fast-slow*, *loud-moderate*; *high arousal-low arousal*, and *high pleasantness-low pleasantness*. All significant activations are displayed in Table 5.1 and Table 5.2.

5.5.2.1 *Activations during listening*. There were significant activations for music conditions (when contrasted with silence, *music* > *silence*) in primary auditory cortex, bilaterally, and in the right cerebellum (see Figure 5.2). Music played at the faster tempo elicited significant activations in left inferior temporal gyrus than did music at the slower tempo (*fast* > *slow*). Music played at the higher intensity elicited significant bilateral activations in supramarginal gyrus and in right inferior parietal lobule (*loud* > *moderate*). Music perceived as highly arousing elicited significant activations in left inferior temporal gyrus, right middle temporal gyrus, and left superior temporal gyrus. Music perceived as highly pleasant elicited significant activations in left fusiform gyrus and right middle frontal gyrus (*high pleasantness* > *low pleasantness*).

5.5.2.2 *Activations during CRT task performance*. There was a significant activation for music conditions (when contrasted with silence, *music* > *silence*) in the right cerebellum. Music played at the faster tempo elicited significant activations in left inferior temporal gyrus, right cuneus, and subcallosal gyrus than did music played at the slower tempo (*fast* > *slow*; see Figure 5.3). Music played at the higher intensity elicited significant bilateral activations in supramarginal gyrus and inferior parietal lobule; and in left putamen, right middle frontal gyrus, and right middle temporal gyrus (*loud* > *moderate*; see Figure 5.4). Music perceived as highly arousing elicited significant activations in left inferior temporal gyrus, middle temporal gyrus (bilaterally), left superior temporal gyrus, left putamen, left subcallosal gyrus, right supramarginal gyrus, left cingulate gyrus, and right inferior parietal lobule (*high arousal* > *low arousal*; see Figure 5.5). Music perceived as highly pleasant elicited significant activations in left fusiform gyrus and in the precuneus (*high pleasantness* > *low pleasantness*; see Figure 5.6).

5.5.3 *Second-Level Analysis: Regions of Interest*

To permit extrapolation of the present findings to the population of interest, a second-level, regions of interest (ROI) analysis was conducted. ROIs with 10 mm radii were identified from the local maxima observed in the first-level (fixed-effects) analysis. The coordinates of unique standalone activations (i.e., where no other activations were present within 10 mm of the activation of interest) were replicated; but where a number of activations shared space within the ROI radius, average coordinates were taken. The mean effect size was determined in each ROI, for each participant. One-sample *t* tests were conducted to examine the statistical significance of the group activations observed. All significant activations are displayed in Table 5.3.

5.5.4 *Individual Data*

Table 5.4 displays a representative selection of individual activations in participants from ROIs that showed significant activation in the second-level analysis (section 5.5.3, above), using coordinates from the first-level analysis. This qualitative approach will allow the reader to more precisely ascertain the anatomical location of the fixed-effects activations depicted in Figures 5.2, 5.3, 5.4, 5.5, and 5.6.

Table 5.1

Significant t-Map Activations by Contrast and Region, for Objective Stimulus Properties

Contrast (condition)	Region	Coordinates			*t* value
		x	*y*	*z*	
Music-Silence (listening)	Superior temporal gyrus	66	-15	6	6.41^{***}
	Superior temporal gyrus	54	-21	6	5.74^{***}
	Transverse temporal gyrus	-54	-24	12	5.62^{***}
	Superior temporal gyrus	-51	-15	3	5.53^{***}
	Superior temporal gyrus	-63	-18	3	5.47^{***}
	Cerebellum (declive)	48	-60	-30	5.44^{***}
	Superior temporal gyrus	60	3	-3	5.07^{*}
Music-Silence (CRT task performance)	Cerebellar tonsil	30	-57	-39	5.29^{***}
Fast-Slow (listening)	Inferior temporal gyrus	-63	-6	-21	5.32^{***}
Fast-Slow (CRT task performance)	Inferior temporal gyrus	-63	-9	-21	5.63^{***}
	Cuneus	18	-96	0	5.52^{***}
	Subcallosal gyrus	-24	6	-15	5.49^{***}
Loud-Moderate (listening)	Supramarginal gyrus	54	-57	30	6.30^{***}
	Inferior parietal lobule	54	-60	42	5.64^{***}
	Supramarginal gyrus	-54	-63	30	6.03^{***}
Loud-Moderate (CRT task performance)	Supramarginal gyrus	54	-57	30	5.76^{***}
	Inferior parietal lobule	51	-60	42	5.66^{***}
	Putamen	-18	6	-12	5.61^{***}
	Supramarginal gyrus	-57	-60	30	5.40^{***}
	Middle frontal gyrus	42	15	45	5.29^{***}
	Inferior parietal lobule	-45	-66	45	5.26^{***}
	Middle temporal gyrus	51	12	-30	4.87^{*}

Note. All observed activations occurred in 3 voxels (27 mm^3) or greater.

* $p < .05$; ** $p < .01$; *** $p < .001$.

Table 5.2

Significant t-Map Activations by Contrast and Region, for Arousal and Pleasantness

Contrast (condition)	Region	Coordinates *x*	*y*	*z*	*t*-value
HA-LA (listening)	Inferior temporal gyrus	-63	-6	-21	5.98^{***}
	Middle temporal gyrus	51	12	-30	5.71^{***}
	Superior temporal gyrus	-57	-60	27	4.99^{*}
HA-LA (CRT task performance)	Inferior temporal gyrus	-63	-6	-21	6.14^{***}
	Middle temporal gyrus	-57	-9	-12	5.17^{**}
	Putamen	-18	9	6	6.00^{***}
	Subcallosal gyrus	-21	3	-15	5.71^{***}
	Superior temporal gyrus	-57	-60	27	5.57^{***}
	Middle temporal gyrus	51	-12	-30	5.40^{***}
	Supramarginal gyrus	60	-57	30	5.25^{***}
	Cingulate gyrus	-9	-45	30	5.17^{**}
	Middle temporal gyrus	57	-66	6	5.16^{**}
	Middle temporal gyrus	-57	-72	21	5.15^{**}
	Middle temporal gyrus	-54	-66	15	5.05^{*}
	Inferior parietal lobule	57	-57	42	4.95^{*}
HP-LP (listening)	Fusiform gyrus	-24	-84	-21	5.13^{**}
	Middle frontal gyrus	36	60	15	5.11^{**}
HP-LP (CRT task performance)	Fusiform gyrus	-24	-84	-21	5.48^{***}
	Precuneus	0	-69	54	5.33^{***}

Note. All observed activations occurred in 3 voxels (27 mm^3) or greater.

HA = High arousal; LA = Low arousal; HP = High pleasantness; LP = Low pleasantness.

* $p < .05$; ** $p < .01$; *** $p < .001$.

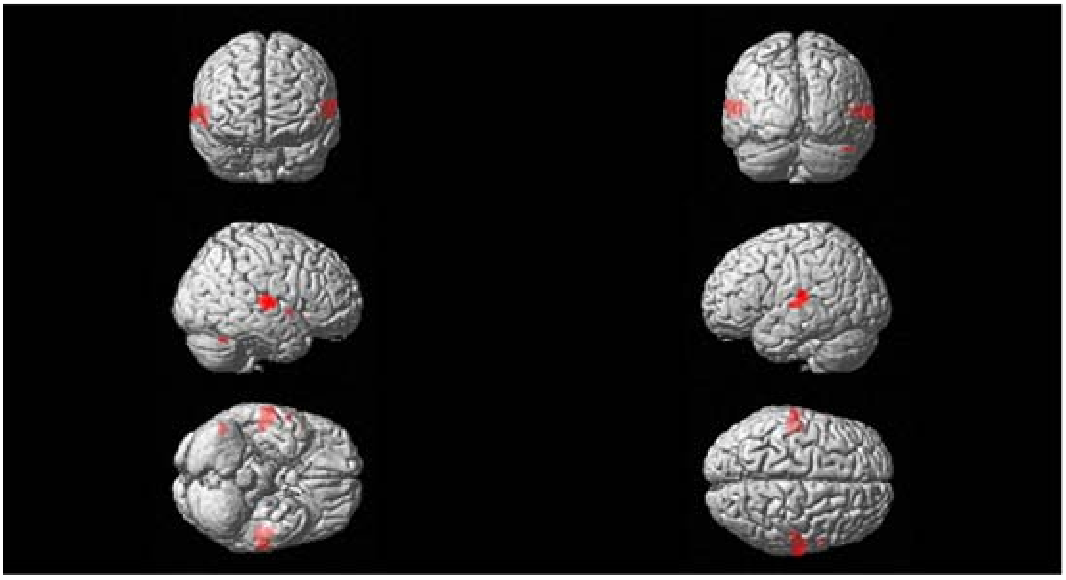


Figure 5.2. Group-level bilateral activation of primary auditory cortex and right cerebellum during music listening (contrasted with silence, *music* > *silence*).

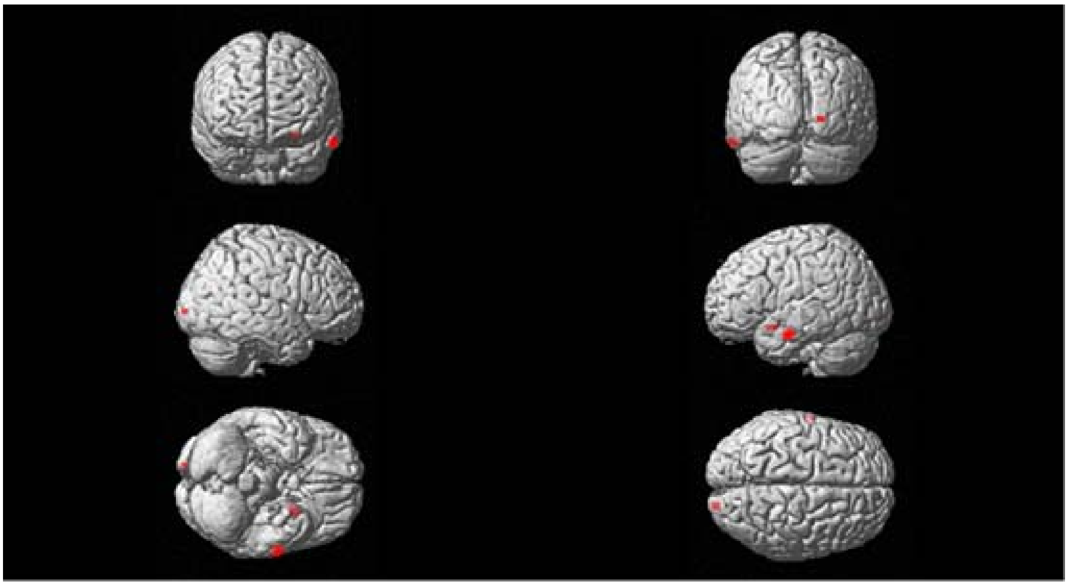


Figure 5.3. Group-level activation of inferior temporal gyrus, cuneus, and subcallosal gyrus during CRT task performance after listening to music played at a fast tempo (contrasted with slow music, *fast* > *slow*).

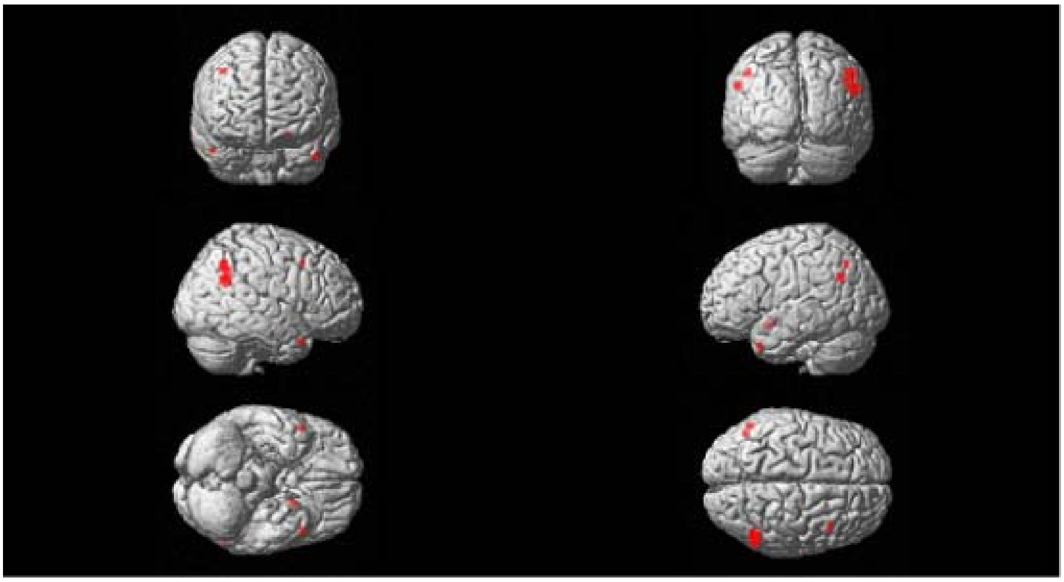


Figure 5.4. Group-level bilateral activation of supramarginal gyrus and inferior parietal lobule; and activation of left putamen, right middle frontal gyrus, and right middle temporal gyrus during CRT task performance after listening to music played at a loud intensity (contrasted with moderate intensity music, *loud* > *moderate*).

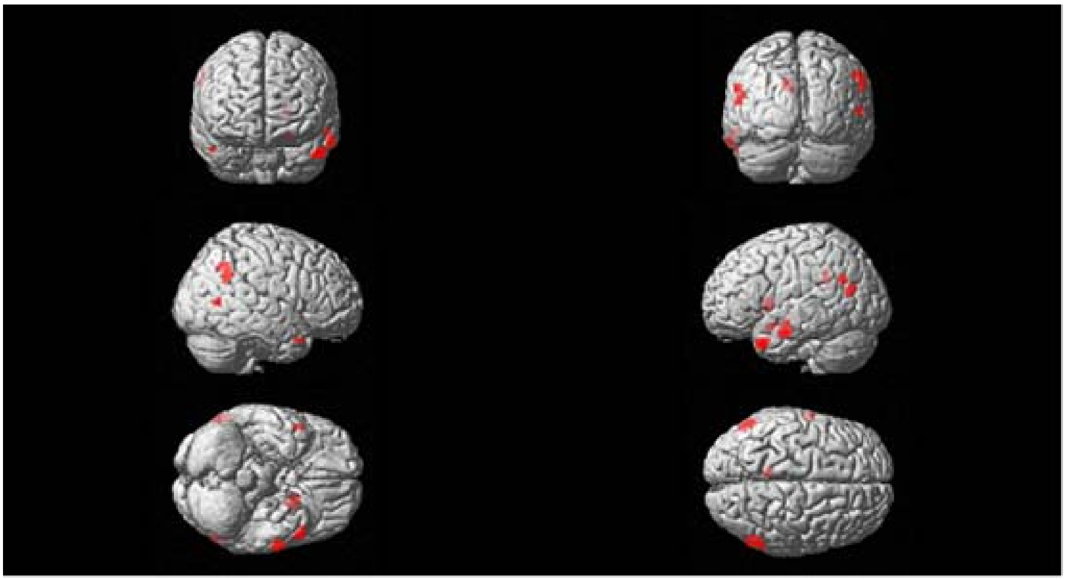


Figure 5.5. Group-level bilateral activation of middle temporal gyrus; and activation of left inferior temporal gyrus, left putamen, left subcallosal gyrus, left primary auditory cortex, right supramarginal gyrus, left cingulate gyrus, and right inferior parietal lobule during CRT task performance after listening to stimuli perceived as highly arousing (contrasted with highly unarousing stimuli, *high arousal* > *low arousal*).

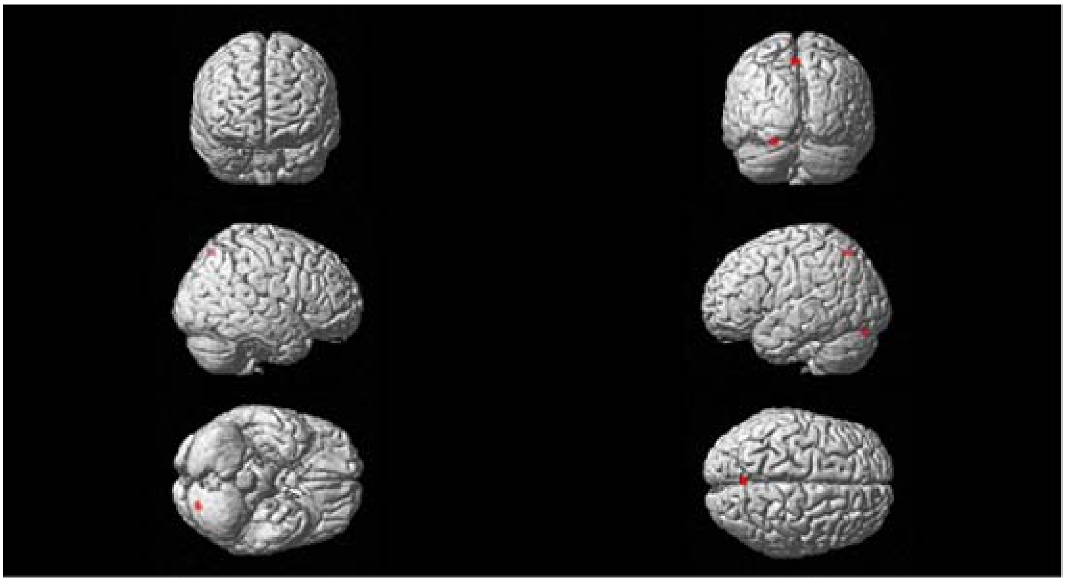


Figure 5.6. Group-level activation of left fusiform gyrus and precuneus during CRT task performance after listening to stimuli perceived as highly pleasant (contrasted with highly unpleasant stimuli, *high pleasant* > *low pleasant*).

5.5.5 *Reaction Time Data*

Reaction time (RT) data in the present study were limited, due to the hardware for transmission of participants' responses to the computer software (E-Prime v.1.1.4.1; Psychology Software Tools, Inc., Pittsburgh, Pennsylvania, US) exhibiting intermittent faults. Many key presses were not registered, and the entirety of three participants' RT data was missing. Also, the sample size in the present study, while possessing acceptable power for fMRI data analysis, was not suitably powerful to examine the small effect witnessed in the previous study. Therefore, these data were considered unreliable, and not analysed.

Table 5.3

Significant Activations by Contrast and ROI

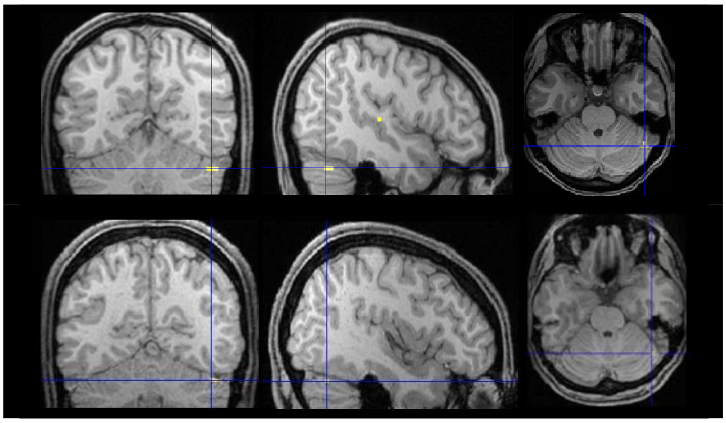
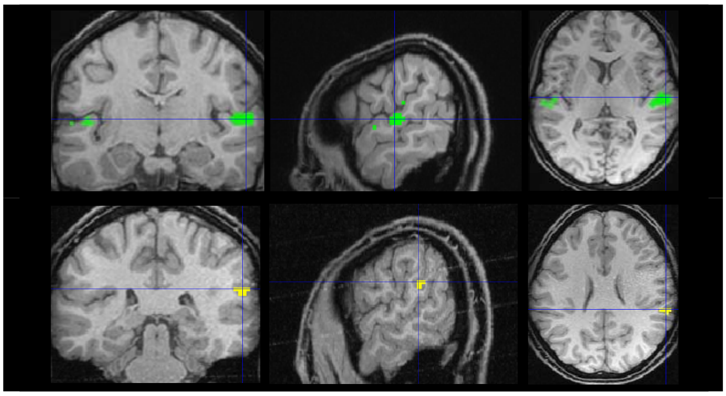
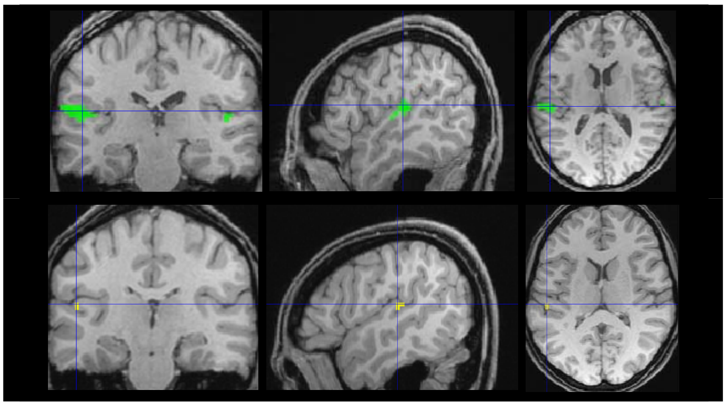
Contrast	ROI	*t*(11)	Mean difference from zero	95% Confidence interval	
				Lower	Upper
Music-Silence (listening)	Right cerebellum	2.46	12.13^{*}	1.26	23.00
	Right STG	3.79	14.50^{***}	6.08	22.92
	Left STG	3.05	10.14^{*}	2.82	17.47
	Left TTG	4.14	10.90^{***}	5.10	16.70
Fast-Slow (listening)	ITG	2.37	2.49^{*}	0.18	4.80
Fast-Slow (CRT task performance)	ITG	2.33	2.46^{*}	0.14	4.79
Loud-Moderate (CRT task performance)	Left putamen	2.81	1.60^{*}	0.35	2.86
HA-LA (listening)	ITG	3.28	15.22^{**}	5.01	25.44
HA-LA (CRT task performance)	Left cingulate gyrus	2.29	12.70^{*}	0.48	24.91
	IPL	2.61	22.76^{*}	3.59	41.94
	ITG	3.59	15.61^{***}	6.05	25.17
	Left putamen	2.68	9.41^{*}	1.68	17.15
	Left subcallosal gyrus	4.00	12.53^{***}	5.64	19.42
HP-LP (listening)	MFG	2.38	25.26^{*}	1.92	48.61

Note. All mean effect sizes were assessed in reference to a hypothesised null mean of zero. STG = Superior temporal gyrus; ITG = Left inferior temporal gyrus; IPL = Right inferior parietal lobule; MFG = Right middle frontal gyrus; Lower = Lower boundary; Upper = Upper boundary

* $p < .05$; ** $p < .01$; *** $p < .005$.

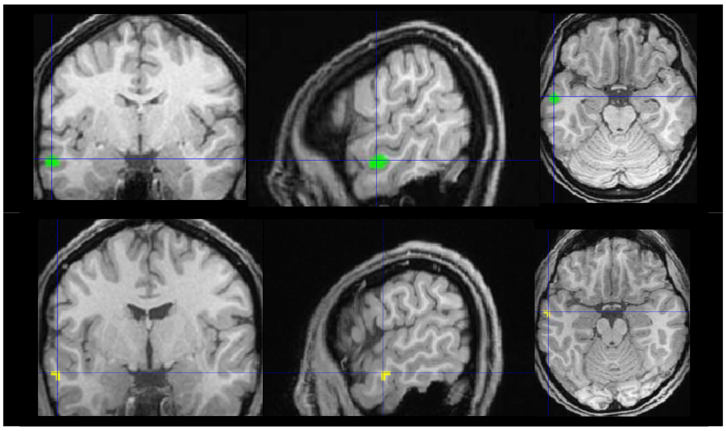
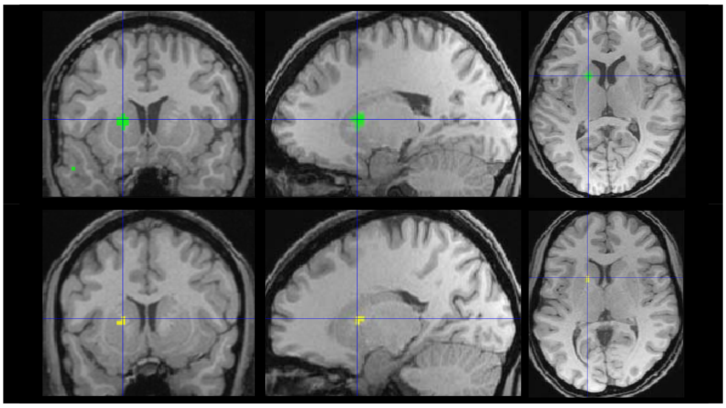
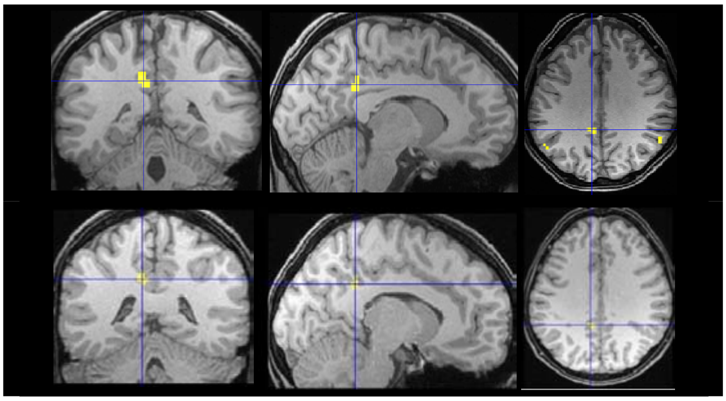
Table 5.4

Individual Activations at Coordinates of Selected Fixed-Effects Activations

Coordinates (region)			Pp	Contrast
x	*y*	*z*		
48	-60	-30	6	*Music* > *silence* (listening) 
(cerebellum)			12	
66	-15	6	1	*Music* > *silence* (listening) 
(superior temporal gyrus)			5	
-54	-24	12	3	*Music* > *silence* (listening) 
(transverse temporal gyrus)			8	

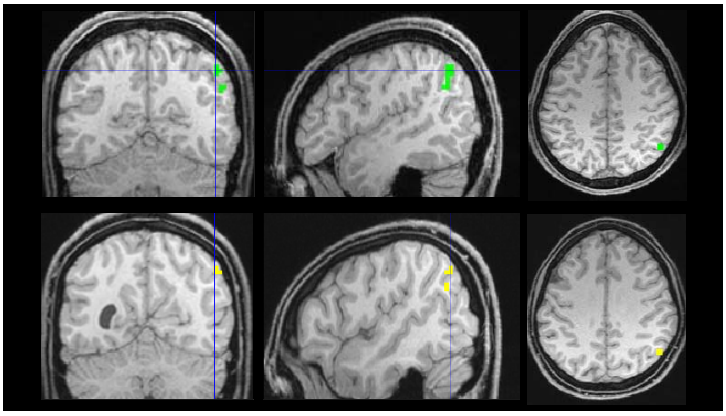
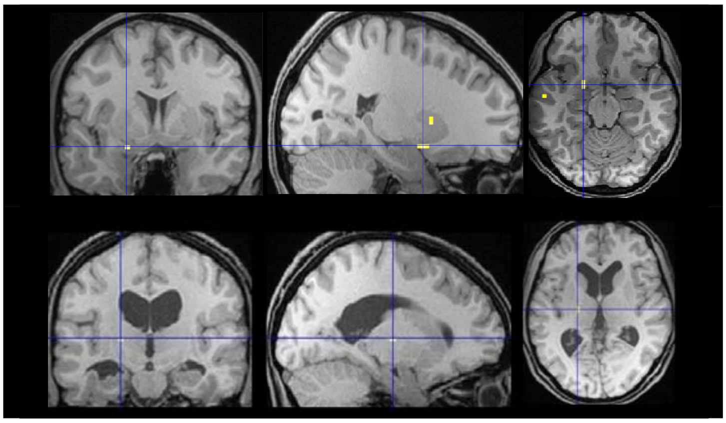
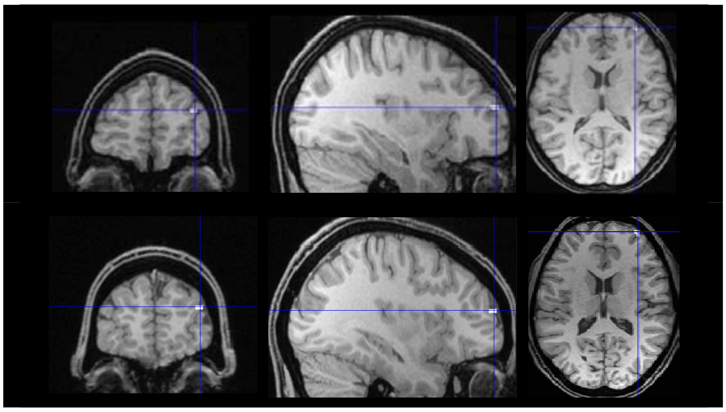
(table continues)

Table 5.4 (continued)

Coordinates (region)				
x	*y*	*z*	Pp	Contrast
				Fast > *slow* (CRT task)
-63	-6	-21	1	
(inferior temporal gyrus)			3	
				Loud > *moderate* (CRT task)
-18	9	6	3	
(putamen)			11	
				High arousal > *low arousal* (CRT task)
-9	-45	30	9	
(cingulate gyrus)			7	

(table continues)

Table 5.4 (continued)

Coordinates (region)				
x	*y*	*z*	Pp	Contrast
57	-57	42	12	*High arousal* > *low arousal* (CRT task) 
(inferior parietal lobule)			4	
-21	3	-15	6	*High arousal* > *low arousal* (CRT task) 
(subcallosal cortex)			4	
36	60	15	1	*High pleasant* > *low pleasant* (listening) 
(middle frontal gyrus)			10	

Note. Pp = Participant.

5.6 Discussion and Conclusions

5.6.1 *Overview*

The present study was conceived as an exploration of the neural correlates of the affective and behavioural consequences of music listening witnessed in the previous study, most importantly during performance of a CRT task. Listening to music yielded greater activation in auditory cortex than did a period of silence, as predicted and supported by previous research (Koelsch et al., 2006); some of these activations were located in superior temporal gyrus, which is a region also active during visual search behaviour (Gharabaghi, Fruhmann, Tatagiba, & Karnath, 2006). There was also greater activity in the cerebellum as a result of listening to music. Bodner et al. (2001) found that the cerebellum was more active after listening to a Mozart sonata (K.448), when contrasted with Beethoven's *Fur Elise* and 1930s piano music; the authors suggested that a study to compare brain areas activated in music listening conditions and in spatiotemporal tasks would be apposite.

Fixed effects analyses showed that listening to loud intensities elicited greater activation in visuomotor areas than stimuli at moderate intensities, although this effect only extended to the putamen in subsequent ROI analyses. There were no significant activations in other visuomotor areas previously associated with improved RT performance, (e.g., occipital cortex and supplementary motor area; Mohamed et al., 2004). Auditory stimuli perceived as highly arousing elicited greater activation in areas involved in visuomotor functions (inferotemporal cortex), sensorimotor integration (inferior parietal lobule), motor control (putamen) and the processing of emotion (e.g., subcallosal cortex; Brown et al., 2004), lending some support to H_3. Fast tempo music did not yield significantly more activation in reward processing structures, although there was some indication of a positive emotional response (subcallosal cortex) and activation of primary visual cortex; only inferior temporal gyrus activation stood up to ROI analysis. Stimuli classified as pleasant did not elicit activation in subcortical emotion/reward-processing nuclei, but this condition did elicit significant activation of right middle frontal gyrus at both first and second levels of the analysis, during listening.

Consistent with Koelsch et al.'s (2006) findings that participants' emotional responses were more pronounced during their second block of auditory stimuli, there was strong evidence of not only residual activation of emotion-processing structures, but also new activations during performance of the CRT task, when contrasted with the listening period. This also finds support from Panksepp (1992), who observed that the neural activation in emotional circuits extends beyond the stimulatory event. This was especially pronounced in the *high arousal* conditions, in which four significant activations subsequently emerged over-and-above the single activation (inferior temporal gyrus) occurring during music listening. All contrasts significant at the second level of analysis, other than *music-silence*, will be addressed sequentially below.

5.6.2 *Contrasts for Tempo and Intensity*

5.6.2.1 *Fast vs. slow*. Fast tempo music did not lead to the expected activations in pleasure centres of the brain (see Berridge, 2003; Blood & Zatorre, 2001) in the present study, despite the fact that tempo is a strong determinant of emotions in music (Peretz, Gagnon et al., 1998; Webster & Weir, 2005). However, fixed effects analyses did reveal some degree of emotional response to faster tempi: There was significant activation in subcallosal gyrus, a structure which has consistently been activated in positive emotional responses to both self-selected familiar music (Blood et al., 1999) and unfamiliar researcher-selected pieces (Brown et al., 2004). The failure of this activation to extend to the second-level of analysis may represent the fact that ecologically valid protocol employed in the present study: The conditions were not as unpleasant or as discordant as selections used in previous studies (e.g., Menon & Levitin, 2005)

Faster music yielded greater activation in early visual cortex (cuneus) in the present study; this may reflect increased activity of distinct saccade neurons, which discharge during saccadic eye movements around and across static stimuli (Snodderly, Kagan, & Gur, 2001). Bradley et al.'s (2003) participants exhibited increased visual cortex activation when viewing emotive stimuli related to primary motive states; Bradley et al. interpreted this as representing a state of "motivated attention", in which either appetitive or defensive motivational states facilitate perceptual processing of stimuli pertinent to the organism's survival. Therefore, the present finding may reflect a low-level emotional response to the faster tempo, in which the individual scans the environment more rigorously. The relevance of faster tempi to survival may be interpreted in terms of their iconic representation (cf. Sloboda & Juslin, 2001) of a more highly aroused, and ergo more motivated, state. In light of Blood et al.'s (2001) observation of decreased activation in the cuneus when participants listened to self-selected chill-inducing music, the heightened activation may arise from a more negative appraisal. The time course of the visual cortex BOLD response at the onset of increased attention is also comparable to that induced by the presence of an actual visual stimulus, with somewhat reduced amplitude (Smith, Cotillon-Williams, & Williams, 2006). Thus, visual cortex activation could reflect participants' heightened anticipation of the CRT task stimuli in between presentations; especially when considering that each blank court screen preceding a target stimulus was 1 s in length, meaning substantially more time (ratio of 3:1 approx.) was spent in the absence of the target stimuli.

The only activation to remain active at the second level of analysis was in the left inferior temporal cortex. This region is a part of the ventral stream of the visual processing system, but has also been implicated in such diverse functions as deactivation in harm avoidance (Sugiura et al., 2000) and in self-reflection – bilaterally (Johnson et al., 2002). Therefore, it is not straightforward to hypothesise about the reasons for activation of inferotemporal cortex in response to fast tempo music. However, because concomitant cuneus activation was observed, one can speculate that some degree of visual processing is responsible. Given the aforementioned withdrawal from activity in avoidance behaviour (Sugiura et al., 2000), it may be the case that this activation represents one component of an approach exploratory response. The presence of solely left-sided activation lends support to asymmetric hemispheric activation theories of motivation (e.g., Heller, 1990), which propose that left hemispheric activation is associated primarily with approach tendencies (see also Schiff & Bassel, 1996).

5.6.2.2 *Loud vs. moderate*. Perhaps unsurprisingly, given the findings from the previous two studies, there was considerable overlap between activations for the *loud-moderate* contrast and the *HA-LA* contrast. However, notable absences in the *loud-moderate* contrast were activations of the emotion-processing structures, cingulate gyrus and subcallosal gyrus, which may suggest some degree of involvement of tempo in eliciting positive emotional responses, in accordance with previous studies (e.g., Webster & Weir, 2005); subcallosal gyrus was activated in fast versus slow music. However, it should be noted that the *loud-moderate* contrast also included loud white noise, which was rated as being of low pleasantness.

Music is used by people, both adolescents and adults, to increase energy (Saarikallio & Erkkilä, 2007; R. E. Thayer, Newman, & McClain, 1994); and participants in Bishop et al.'s (in press) study selected high intensities for music designed to psych-up. However, explanations for why this may be the case are lacking. Higher sound intensity in the present study yielded greater activation in the putamen, which is involved in motor control. Also, music per se increased cerebellar activation relative to silence. To perceive (i.e., to *hear*) music requires the transfer of sound energy from the transducer (e.g., earphones) to the mechanisms of the inner ear. Higher sound intensity means a transfer of more energy to the inner ear; and auditory and vestibular structures are arranged intimately, before their respective nerves conjoin to form the vestibulocochlear nerve. Thus, the increased energy may be transferred to the vestibular apparatus, which results in cerebellar and striatal activation, in an attempt to bring perceived unwanted movement under volitional control; a similar principle forms the basis for the technique of galvanic vestibular stimulation, which functional imaging has shown to activate the cerebellum (Stephan et al., 2005).

5.6.3 *Contrasts for Valence and Arousal*

5.6.3.1 *High Arousal vs. Low Arousal*. The *high arousal-low arousal* contrast accounted for the greatest number of activations overall, which represents a strong corroboration between the affective response (i.e., subjectively high arousal) and a neurophysiological state that implies a general neuropsychological level of activation which may be mediated principally by the ascending reticular activating system (Malmo, 1959). Increased cortical activation also appears to have implications for information processing ability in reactive tasks: Winterer et al. (1999) found that the degree of pre-stimulus delta activity (an important component of sleep EEG) was negatively correlated with reaction time (RT) performance; post-stimulus cortical noise was also significantly correlated with RTs. In addition to subcallosal cortex, whose activation has been previously identified in positive emotional responses to music (Blood & Zatorre, 2001; Brown et al., 2004), posterior cingulate gyrus was also activated. This may represent an augmented emotional response that involves some degree of self-reflection (Johnson et al., 2002); an idea which is supported by its activation during conscious resting states (Mazoyer et al., 2001). However, this idea of self-reflective contemplation during wakeful rest does not correspond well the improved performance seen in the previous chapter, under this condition.

The inferior parietal lobule (IPL) was also significantly activated in the ROI analysis, in the high arousal conditions relative to low arousal conditions. The IPL is an area for sensorimotor integration, receiving input of visual information from the superior colliculus, as well as inputs from the hippocampus and cerebellum (Clower, West, Lynch, & Strick, 2001). Activation of IPL in the processing of apparent motion appears to be dependent on the level of attention to the stimulus (Claeys, Lindsey, De Schutter, & Orban, 2003). Therefore, the heightened activation witnessed may represent the culmination of increased attention to the target stimuli in the present study, which did not move, but could be perceived as moving. Increased activation of IPL has implications for the development of automaticity in self-paced sports (Kerick, Douglass, & Hatfield, 2004), so using music to attain a state of subjective arousal during practice may facilitate learning; a concept which has been demonstrated in karate (Ferguson et al., 1994).

There were no significant activations in motor cortex, premotor cortex or supplementary motor area (SMA) as a result of listening to highly arousing stimuli. This may be due to the fact that participants were relatively still. The striatum – which was activated under arousing conditions – receives cortical input via the descending corticostriatal pathway, and channels it into the SMA, which is involved in making adjustments prior to performing reactive motor operations (Toma et al., 2003). Therefore, one might expect its activation at some point in the present protocol. However, the effect on the cortex of the increased activity observed in the striatum is likely to be more diffuse, rather than just focused on the active area which was predominantly active in the present study – the thumb. Also, the actual area unequivocally devoted to a single digit is comparatively small (Indovina & Sanes, 2001). A future study to target a muscle group which recruits a greater number of motor neurons (e.g., the arm flexors) may uncover a greater level of activity. An alternative explanation for the increased activity in putamen may be its putative role in generating saccadic eye movements in visual search behaviour (Hikosaka, Takikawa, & Kawagoe, 2000); this would also fit well into an approach behaviour theoretical framework.

5.6.3.2 *High pleasant vs. low pleasant*. Ashby et al. (1999), noted that positive affect can lead to enhanced cognitive functioning; an effect which may be mediated by increased levels of dopamine in dopamine-producing areas such as the ventral tegmental area and substantia nigra, which collectively project to anterior cingulate cortex, nucleus accumbens, striatum and the locus coeruleus. Pleasant states in the present study led to significantly greater activation in the second-level analysis, of the middle frontal gyrus (MFG) only. The MFG has been implicated in shifting of spatial attention (Macaluso, Frith, & Driver, 2001), and activity in this region may also reflect enhanced attentional awareness (Wiese, Stude, Nebel, Forsting, & de Greiff, 2005). It is also displays lateralization of function, during decision-making tasks: the right side appears to deal more with ‘where’ processing (Talati & Hirsch, 2005), which is consistent with the notion that participants were anticipating where the first stimulus was going to appear on the screen.

Although the activations expected in response to pleasant auditory stimuli were not observed in the present study, conditions eliciting higher subjective arousal might conceivably have constituted a more subjectively pleasant state also, as the participants were in the scanner for long periods of time (≈ 60 min), and the reduced environmental stimulation might ultimately have led to reduction in pleasant feelings. This was corroborated by activation in subcallosal cortex when listening to arousing stimuli. Subcallosal cortex has been consistently activated in emotional responses to pleasant music (Blood et al., 1999; Brown et al., 2004); and decreased activity in this region has also been observed in depressed individuals (Drevets et al., 1997). One key feature of major depressive episodes is a loss of energy (R. E. Thayer, 1989); therefore, the activations observed during high arousal in the present study may, in fact, represent higher positivity/pleasantness.

Fixed effects analyses showed increased activation of the fusiform gyrus when listening to auditory stimuli perceived as pleasant, and this activation increased into the CRT task. The fusiform is a visual information processing area, and the area activated in the present study has been implicated in short-term retrieval of the spatial locations of visual stimuli (Lacquaniti et al., 1997) The increased activation observed in fusiform gyrus during both listening and performance of the CRT task may reflect the fact that the participants were actively attempting to anticipate appearance of the visual stimulus. The precuneus was also activated in the first-level analysis, but it's relation to emotional valence as a result of music listening is far from clear (Blood & Zatorre, 2001; Blood et al., 1999).

Although participants in Study 2 rated white noise as significantly less pleasant than music, there was no (expected) NAc activation as a result of music listening; this was possibly due to the fact that white noise contributed to overall acoustic noise in the scanner, which can ameliorate perceptions of pain (Boyle, Bentley, Watson, & Jones, 2006). Activation in nuclei of the ventral striatum is related to intensely pleasurable responses to music (Blood & Zatorre, 2001), but the responses witnessed in the present study were arguably not intense – whether pleasurable or otherwise. Indeed, mean pleasantness ratings in the previous study of the present research programme showed that all stimuli – with the exception of loud white noise – were at least moderately pleasant.

5.6.4 *Approach Responses*

There was some evidence that the auditory conditions associated with high arousal supported Heller's (1993) model of brain activity in emotions: There was heightened activity in right parietotemporal area. There was also considerable left-sided activation in other areas, although this was not frontal lobe activity (e.g., inferior temporal gyrus). The activations witnessed in *pleasant* versus *unpleasant* conditions might have represented an approach response (Gray, 1994); this is also supported by the work of Heller (1990), Schmidt and Trainor (2001), J. F. Thayer and Faith (2001), and Davidson, Jackson, and Kalin (2000). We might also have expected greater left hemispheric activation in response to self-selected music, which is unarguably likely to be considered far more liked than the researcher-imposed selections used in the present study.

Panksepp proposed an innate SEEKING system that is sensitised primarily by regulatory imbalances to yield general arousal and persistent forward locomotion; and secondly, by external stimuli that either strongly or weakly interact with this system. He proposed that this system affords classical conditioning of cues that have been associated with activation or deactivation of this system. The central controller of the SEEKING system is the lateral hypothalamus corridor; a dopaminergic pathway. Subsequent research has indicated the activation of a similar arrangement of subcortical structures in the processing of emotional stimuli – pleasant or unpleasant (Lane et al., 1997).

Faster and louder music may have a weak interaction with the emotional system, which has emerged through conditioning, via Panksepp's SEEKING system. Happy and sad music can activate dopaminergically innervated structures similarly to other, more biologically-relevant, stimuli (Khalfa et al., 2005), suggesting that the reward system may indeed be activated through a conditioning process. Music with a faster tempo may, for example, be more indicative of happier states (cf. Webster & Weir, 2005); this would tend to fit with social music use (e.g., people listen to faster music at parties, which are typically positive and rewarding social contexts). Panksepp suggests a role for music in stimulating the SELF, to yield what he describes as an "eager interest" – or hedonistic seeking-type behaviours. However, arousal is a greater determinant of subsequent attention than is valence (Anderson, 2005), and this is reflected in both EEG correlates of auditory CRT performance (Winterer et al., 1999), and the degree of activations witnessed in the present study.

5.6.5 *Limitations*

There were no activations in emotion-processing structures witnessed in previous studies. However, there is evidence to suggest that emotional responses need not be confined to primary emotion-processing structures; they can exist after ablation of medial temporal cortex (Samson & Peretz, 2005). The failure to witness activations in subcortical emotion-processing structures (e.g., hippocampus; Fendt, Fanselow, & Kock, 2005; Gosselin et al., 2006; Lane et al., 1997) in the *pleasant-unpleasant* contrast is likely due to the fact that the unpleasant conditions were not particularly unpleasant, unlike the unpleasant stimuli used in previous studies (Blood & Zatorre, 2001; Koelsch et al., 2006). Unpleasant musical stimuli in other studies are often scrambled versions (e.g., Gosselin et al., 2006). However, the present protocol was far more ecologically valid, in that the valence of the music heard by an athlete during their pre-performance preparation is only liable to vary within a narrow range; if exposed to a highly disliked piece of music, removal of either themselves or the music stimulus is a more likely course of action than is sufferance (cf. Colman, Hargreaves, & Sluckin, 1981; Colman, Sluckin, & Hargreaves, 1981).

One patent methodological weakness of the present study is that ratings of arousal and valence were conducted separately from the bouts in the scanner, which may mean that they do not accurately reflect the emotional response in the scanner itself. However, music has the ability to interact with emotional stimuli in the visual environment (Baumgartner, Esslen et al., 2006; Baumgartner, Lutz et al., 2006), to elicit more pronounced emotional responses. Also, the use of the Affect Grid (Russell, Weiss et al., 1989) in the scanner was not viable, due to the fewer response options afforded by the button box.

Some contrasts were difficult to elicit, because the signal-to-noise ratio was low. For example, silence constituted only one period of 90 s, which was contrasted with 6 x 90 s music periods. Clustered volume acquisition may improve data acquisition, because this has the advantage of not contaminating the auditory activation with that derived from scanner noise (Edmister, Talavage, Ledden, & Weisskoff, 1999). It may be for this reason that no activations were uncovered in the primary machinery of simple emotional responses to music, such as in the hypothalamus, nigrostriatal pathway, and mesolimbic dopaminergic system (e.g., Blood & Zatorre, 2001; Blood et al., 1999; Brown et al., 2004; Koelsch et al., 2006).

5.6.6 *Recommendations for Future Research*

Menon and Levitin (2005) established connectivity of the nucleus accumbens, a ventral striatum area, with the ventral tegmental area in response to music; and another closely related area, the locus coeruleus, has been implicated not only in attentional and behavioural flexibility (Aston-Jones, Rajkowski, & Cohen, 1999), but also in the neurobiology of reward (Esch & Stefano, 2004). Although there was no activation of ventral striatum in the present study, as per previous studies (Blood & Zatorre, 2001), the activation of dorsal striatum (putamen) – an area with some degree of connectivity with ventral striatum – might have been related to perceptibly rewarding stimuli. Future research should seek to examine the connectivity of these anatomically intimate structures, in order to elucidate any potential role for music in eliciting coordinated motor/emotion responses.

One notable absence in the present study is the lack of reaction time data, which was not available due to unforeseen problems in data acquisition, which rendered its interpretation unviable. In future, an event-related design may be employed to examine music-performance correlates. However, the operation of the button box in the scanner is not a particularly ecologically valid modus operandi for competitive tennis players; nor could it reasonably be expected to approximate the performance required for reactive skills in other sports. The future development of new methods for (a) affording CRT responses from inside an MRI scanner, and (b) reducing or removing movement- and blood flow-related artefacts from the data acquired, could circumvent this present methodological weakness.

There were no significant activations of motor structures in the present study, over-and-above that in the putamen. Moreover, there was considerable evidence that listening to auditory stimuli perceived as both pleasant and arousing, played at a fast tempo and a loud intensity, may yield increases in visual attentiveness. Because the motor output (i.e., CRT performance) is of ultimate interest, it would be prudent to examine further the role of motor pathways in the performance improvements witnessed in the previous chapter. Explicitly, an evaluation of the effects of listening to fast, loud – and subjectively pleasant and arousing – music on corticospinal excitability is warranted.

5.6.7 *Summary*

The present study represents a unique approach to the investigation of the neural basis of emotional responses to music. Somewhat surprisingly, there was a comparative dearth of activations after listening to music per se, when contrasted with silence. Additionally, while fast tempo and loud intensity only promoted greater activation in visuomotor areas (inferior temporal gyrus and putamen) at the second level of analysis, valence and arousal contrasts collectively revealed activation of structures involved in both emotion-processing (Berridge, 2003) and decision-making (Talati & Hirsch, 2005). Taken together these findings highlight the imperative that researchers acknowledge the relative contributions of situational, personal, and music factors to emotional responses to music (Bishop et al., in press; Gabrielsson, 2001; Saarikallio & Erkkilä, 2007). The results presented herein are by no means conclusive, but provide a number of suitable leads for further research efforts. The chief contribution of the work presented here, has been the identification of neural bases for the impact of emotional responses to music on subsequent physical performance.

CHAPTER 6: CORTICOSPINAL EXCITABILITY IN EMOTIONAL RESPONSES TO PRE-PERFORMANCE MUSIC

6.1 Introduction

Research into the ergogenic effects of music as an accompaniment to physical activity has commonly examined motor output as an outcome variable. Listening to music can improve ergometer cycling performance (Anshel & Marisi, 1978; Elliott et al., 2003), and increasing the music tempo at key junctures of performance may be a valid means by which to enhance this effect (Szabo et al., 1999). Faster tempi appear to contribute to the motivational effect of music during stationary cycling (Atkinson et al., 2004), and Karageorghis' (2000) examination of synchronous and asynchronous music suggested that there is a tendency for participants to coordinate movement with the musical beat.

There is further evidence that tempo may mediate music's ergogenic effect on motor output in local muscular strength and endurance tasks. Pearce (1981) noted that concurrent listening to music classified as *sedative*, according to Gaston's (1951) earlier definitions (see Section 2.3.2.3.1), significantly decreased participants' performance on a grip strength task. Karageorghis et al.'s (1996) participants also exhibited greater grip strength after listening to *stimulative* music (tempo 134 bpm) when contrasted with sedative music (90 bpm) and white noise control conditions. However, Thaut et al.'s (1991) earlier work provided electromyographic evidence that the matching of rhythmic work output to the beat of music during performance of a simple motor task brought about potentially counterproductive contraction of the primary antagonist (triceps) for the desired movement.

The notion of motor behaviour as an intrinsic component of emotion is common to many discussions of emotion phenomena (Frijda, 1987; Izard, 1991); moreover, motor behaviour is described in terms of appetitive and aversive motivational systems by a number of theorists (e.g., Gray, 1994; Panksepp, 1998). This view of emotions as fundamentally motivational states is encapsulated by Lang (1995), who described them as "…action dispositions – states of vigilant readiness that vary widely in reported affect, physiology and behavior" (p. 372). Music has the ability to elicit such utilitarian emotions (Scherer, 2004), which can serve evolutionarily adaptive functions. Faster music tempi have been associated with not only greater levels of positive affect (Dalla Bella, Peretz, Rousseau, & Gosselin, 2001; Webster & Weir, 2005), but also higher levels of arousal in sport (Bishop et al., in press); both of these affective states appear to enhance cognitive and/or motor functioning in decision-making tasks (Ashby, Isen, & Turken, 1999; Bishop & Karageorghis, 2007).

The human corticospinal tract contains over a million fibres, and approximately 50% of these originate from primary motor cortex (Mills, 1999). Transcranial magnetic stimulation (TMS) offer a method by which changes in excitability of the corticospinal tract can be measured; these changes are reflected in a number of ways: The amplitude of the motor evoked potentials (MEP) in response to TMS pulses, the latency between TMS pulse onset and MEP onset, and the intensity of stimulation (expressed as a % of maximum) required to evoke a minor EMG response of a certain amplitude with a given probability – referred to as the *motor threshold* – all are accepted indices of the excitability of the motor corticospinal pathways (Maeda & Pascual-Leone, 2003). Corticospinal excitability is typically in a permanent state of flux, and measures obtained may be influenced by a number of factors, such as attention (Kiers, Cros, Chiappa, & Fang, 1993), fatigue (Hollge et al., 1997), activity of neighbouring muscles (Hess, Mills, & Murray, 1986), and caffeine ingestion (Cerqueira, de Mendonca, Minez, Dias, & de Carvalho, 2006). There is also evidence of increases in cortical excitability prior to the execution of external movements in response to visual cues. Davey, Rawlinson, Maskill, and Ellaway (1998) observed an increase in MEPs, as the time between the stimulus pulse and voluntary movement EMG decreased. However, Nikolova, Pondev, Christova, Wolf, and Kossev (2006) subsequently noted that single pulse TMS delivered prior to voluntary movement can either reduce or lengthen subsequent reaction time, if the pulse-movement interval was short or long, respectively. Therefore TMS may not be an appropriate investigative tool if reaction time is a variable of interest, when pulses are delivered during, or immediately prior to, task performance.

A number of investigators have examined cortical activity as an index of emotional responses to music. Schmidt and Trainor (2001) examined frontal and parietal lobe EEG activity as a function of listening to musical of varying emotional valence and intensity. Participants heard four 60 s excerpts which the authors believed to collectively reflect emotions from each of the four quadrants of the circumplex model (Russell, 1980): Intense-unpleasant (e.g., fear), intense-pleasant (e.g, joy), calm-pleasant (e.g., happiness), and calm-unpleasant (e.g., sadness). Parietal and frontal EEG recordings were taken continuously throughout each excerpt. While parietal analysis revealed no significant effects, positively valenced music elicited significantly greater overall frontal lobe EEG activity than did negative valenced music. High intensity emotions (i.e., joy and fear) elicited greater frontal activity overall, also. Moreover, there was a significant interaction: High intensity, positively valenced music elicited significantly greater EEG activity. The authors concluded that it is possible to distinguish between both valence and intensity of emotions based on frontal EEG patterning.

Kallinen and Ravaja (2004) also used a dimensional model of emotion, that of Larsen and Diener (1992), in their multicomponential investigation of the impact of personality variables on emotional responses to music. Using the BIS/BAS scales (Carver & White, 1994) and the Zuckerman-Kuhlman Personality Questionnaire (Zuckerman, Kuhlman, Joireman, & Teta, 1993) as personality measures, the authors examined participants' emotional ratings, EEG and cardiovascular responses to 12 researcher-selected excerpts that varied in emotional quality and intensity. Those participants with high BAS-FS (fun-seeking;

arguably comparable to extraversion) scores showed a significant decrease in alpha activation as a result of listening to music, while those scoring low on the same dimension showed a significant increase; the former group also exhibited significantly lower negative activation as a result of listening to music. Interestingly, there were no significant effects of personality or condition (pre- or post-music) on central alpha activation – which may be partly reflective of motor cortex activity. The authors noted that EEG data did not corroborate self-report or cardiovascular data, however; there was also a strong mediating effect of personality, implicating enhanced efficacy of music for those prone to anxiety and with neuroses. Electrophysiological data to support the idea that music can ameliorate negative affective states has since been put forward by Sokhadze (2007), who noted that music – irrespective of valence – could promote recovery of participants' electrocortical activity after viewing pictures which elicited strong disgust.

Amezcua et al. (2005) investigated the effect of manipulating the tempo of three of Bach's preludes on performance of a choice reaction time task. Event-related potentials (ERPs) were recorded from six locations according to the International 10-20 System. Reaction times were significantly shorter when listening to music played at a fast tempo (185 bpm), as compared to baseline (no music) values. Fast tempo music also elicited shorter latencies for ERPs related to stimulus evaluation, in relation to both baseline and music played at slow tempo (60 bpm). In their explanation of the possible origins of such potentials, Amezcua et al. implicated the involvement of anterior cingulate cortex (ACC) as an interface for emotional responses to music and cognitive process (cf. Allman, Hakeem, Erwin, Nimchinsky, & Hof, 2001); the ACC has been previously identified as one of the origins of the P300 potential – an index of the orientation of attention to significant stimuli (Halgren, Marinkovic, & Chauvel, 1998).

Studies into the effects of music on corticospinal excitability are few. One notable exception is that of Wilson and Davey (2002), who examined the effect of listening to strongly rhythmic music on the corticospinal excitability of the ankle flexor (tibialis anterior; TA) and ankle extensor (gastrocnemius; GN) muscles used during foot-tapping behaviour, such as that observed in response to music. They delivered blocks of 50 TMS pulses at 120% of motor threshold to participants in each of five conditions: During white noise (muscles relaxed); during music, delivered on the beat (muscles relaxed); during music, delivered midway between beats (muscles relaxed); during music, delivered on the beat (with active foot tapping); and during music, delivered midway between beats (with active foot tapping). There was no difference in the area of the MEPs between blocks in which muscles were relaxed, suggesting that music per se was not enough to promote motor activity in these muscles. However, music enhanced MEPs as a result of TMS pulses delivered both on and midway between beats, when compared with the white noise condition. Importantly, there was also a marked decrease in the correlation of MEP areas in TA and GN during music when compared with those in the white noise condition, when muscles were perceptibly relaxed, suggesting potential rhythmic – and subliminal – changes in corticospinal drive as a function of music listening.

Baumgartner, Willi, and Jäncke (2007) investigated the combined effect of emotive music and pictures of congruent valence on corticospinal excitability. Participants were required to provide immediate post hoc ratings of valence and involvement with music, pictorial and combined stimuli depicting each of three emotional valences (Fear, Sadness, Happiness). Skin conductance responses and MEPs were recorded during stimuli presentation. Participants rated the combined conditions most extremely for valence, when contrasted with listening to music or viewing pictures only (e.g., the Happy condition was rated as significantly more positive); they also rated themselves as more highly involved with the stimulus. Although music elicited similar skin conductance responses when compared to combined stimuli, greater MEP amplitudes were elicited for combined stimuli, across all three conditions. Baumgartner et al. suggested that the increase in vegetative arousal in response to music is perhaps a necessary, but not sufficient, precondition to increased motor system activation; and argued that the higher evolutionary significance of visual stimuli to the organism – especially when coupled with the enhanced arousal arising from music listening – was responsible for the differences witnessed in MEPs. It is worthy of note, however, that Baumgartner et al. did not contrast music with silence, which will be the case in the present study.

6.1.1 Methodological Considerations

6.1.1.1 *Transcranial magnetic stimulation*. Transcranial magnetic stimulation (TMS) is a procedure for non-invasive stimulation of the human corticospinal tract (Taylor & Gandevia, 2005). A large current is generated by a bank of capacitors, which flows rapidly (rise time ≈ 200 μs) through a stimulating coil held close to the scalp. Magnetic induction dictates that the changing field acts on charges in the tissue it passes through, causing small local currents to flow. If these currents are sufficient, depolarisation of the neuronal membrane occurs, resulting in an action potential. Given its exceptional temporal resolution (pulse duration of approximately 0.3-1.0 ms), TMS is a powerful neuroimaging technique for measuring the excitability of specific corticospinal motor pathways. Although there are safety concerns regarding the use of repetitive TMS (Wasserman, 1998), this is not the case for single-pulse TMS – which will be used in the present research programme.

6.1.1.2 *Measures of corticospinal excitability*. Motor evoked potentials (MEPs) are electrical potentials recorded from peripheral nerves, muscles, or the spinal cord as the outcome of CNS motor pathway stimulation (e.g., by TMS), and their amplitude reflects corticospinal excitability. The latency of their onset, defined as the time elapsed between the onset of the TMS pulse and the onset of the MEP, is also an index of corticospinal excitability. The motor threshold refers to the minimum stimulation intensity, specified as a percentage of the maximum possible, which is required to elicit an MEP of a given criterion with a specified probability; these criteria vary somewhat according to different sources (e.g., Mills & Nithi, 1997; Reutens & Berkovic, 1992; Rossini et al., 1994).

6.1.1.3 *Stimulating coils*. Stimulating coils comprise tightly wound and well insulated copper coils together with temperature sensors and safety switches. Typical coils are circular in shape, and the highest field strength is generated near the centre windings – approximately under the mean diameter of the coil. The induced tissue current is opposite in direction to the current flowing in the coil; this has implications for stimulation of human motor cortex, which is more sensitive to induced current flowing in the posterior-to-anterior direction (Jalinous, 1998). Double coils, which comprise two coils side-by-side, improve the focus of stimulation: The strength of the induced tissue current is greater, and is at its maximum under the point at which the two coils meet (see Figure 6.1; red represents the highest field strength, while blue represents the lowest).

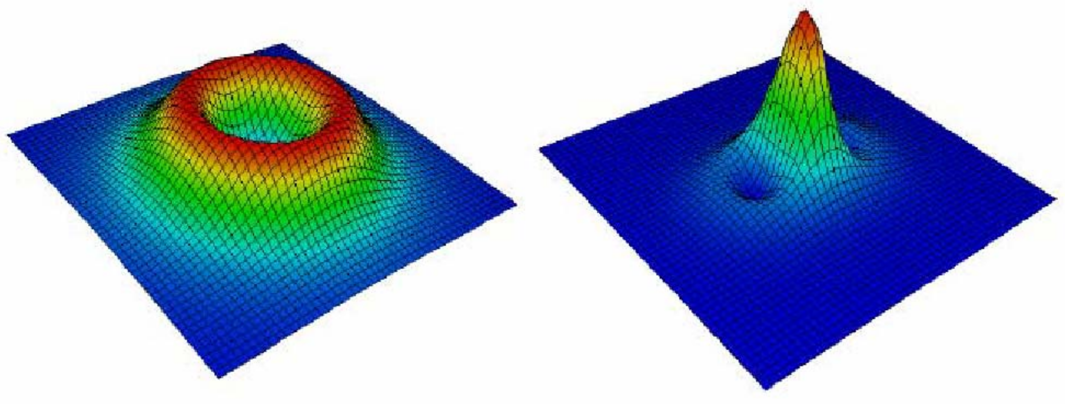


Figure 6.1. The induced electric field profiles for a circular coil (left) and a double coil (right).

6.1.1.4 *Surface electromyography*. Muscle fibres generate small electrical currents prior to the production of muscle force, which are generated by the exchange of ions across muscle fibre membranes, a part of the muscle fibre contraction signalling process. The resultant signal, called the electromyogram, can be measured by applying conductive elements or electrodes to the skin surface, or intramuscularly. Surface EMG (sEMG) is the more common method of measurement, as it is non-invasive and can safely be conducted by untrained personnel. Measurement of sEMG is dependent on a number of factors, and the amplitude of the sEMG signal varies from the μV to the low mV range (Basmajian & De Luca, 1985). The amplitude, time and frequency domain properties of the sEMG signal are dependent on factors such as (a) the timing and intensity of muscle contraction; (b) the distance of the electrode from the active muscle area; (c) the properties of the overlying tissue (e.g., thickness of overlying skin and adipose tissue); (d) the electrode and amplifier properties; and (e) the quality of contact between the electrode and the skin (Gerdle, Karlsson, Day, & Djupsjöbacka, 1999). Much of the sEMG signal variability can be minimized through using the same electrodes and amplifier, and by ensuring consistency in the quality of contact between the electrodes and the skin (Zipp, 1982). Nonetheless, the signal from sEMG is still far more prone to cross-talk from other muscles than is EMG obtained from intramuscular wire electrodes, as evidence in the splenius capitis muscle of the neck, for example (Benhamou, Revel, & Vallee, 1995).

6.2 Rationale for the Present Study

Tempo is an intrinsic property of music which has been successfully used to manipulate both physical performance (Szabo et al., 1999) and emotional responses (Webster & Weir, 2005) – typically yielding increased work output and positive affect, respectively. Music played at faster tempi has been shown to elicit higher subjective arousal in sporting contexts (Bishop & Karageorghis, 2007); and both positively valenced and high intensity emotional responses to music elicit greater frontal lobe EEG activity (Schmidt & Trainor, 2001). Ashby et al. (1999) suggested that increased nigrostriatal (dopaminergic) activation of the striatum may be partly responsible for increases in positive affect and concomitant cognitive performance improvements. Dopamine is released in response to rewarding stimuli and leads to increased motor behaviour, as elucidated in neurophysiological models of appetitive emotion-driven motivation systems (e.g., Panksepp, 1998) The neostriatum, incorporating the putamen, increases excitation of supplementary motor area (SMA, Mills, 1999), which has been shown to enhance hand MEP amplitudes in response to emotive stimuli (Oliveri et al., 2003).

The basal ganglia, incorporating the striatum, have not only been implicated in selection of behavioural responses to Pavlovian conditioned stimuli (Rolls, 2005), but also operate as part of a motor feedback loop which funnels widespread cortical activation onto the SMA. Primary motor cortex (M1) is another integral part of this loop that maintains not only strong, dense synaptic connections with motor neurons and their associated spinal interneurons, but also with the basal ganglia (Bear, Connors, & Paradiso, 2007). Increased activity in the putamen (part of the striatum) was found as a result of listening to both louder and more arousing auditory stimuli in the foregoing study. However, there was no concomitant activation witnessed in SMA or M1, nor in premotor cortex. Evidence from both the extant body of literature and the current thesis, as presented herein, suggests that the combined effect of listening to fast, loud music which is considered subjectively arousing should heighten not only affect, but also activation of the motor pathways to a marked degree. Therefore, further exploration of the effects of such music on motor cortex excitability is warranted.

6.3 Aim and Hypotheses

Neurophysiological data from Chapter 5 indicated several significant activations of neural structures as a result of listening to music, both during music listening and during subsequent CRT performance, which may partly explain the performance improvements witnessed in Chapter 4. One notable exception was the absence of significant activations in supplementary motor area, premotor cortex, or primary motor cortex. Therefore, the aim of the present study was primarily to use TMS to investigate the extent to which music selected according to specific criteria could increase corticomotor excitability. Specifically, fast tempo music that is considered to be both arousing and pleasant by a pilot sample demographically similar to the intended main study sample, will be selected and played at a loud intensity during acquisition of both affective and MEP data. This will be contrasted with baseline values and those derived from a period of silence. Because motor output *subsequent* to music listening is also of major interest, EMG data will also be collected during performance of a simple CRT task immediately thereafter, in each of the three conditions. The following hypotheses are proposed:

H_1 Listening to fast tempo (150 bpm) loud intensity (75 dBA) music, deemed by a pilot sample to be both pleasant and arousing, would be rated as significantly more arousing than would a period of silence of equivalent duration.

H_2 Motor corticospinal excitability, as evinced by motor threshold, MEP amplitude and latency measures, will be increased during listening to the aforesaid music, when contrasted with a period of silence.

H_3 Subsequent EMG amplitude and latency will be increased and decreased, respectively, during performance of a CRT task after listening to music, when contrasted with silence; and this will be reflected in shortened reaction times.

6.4 Method

6.4.1 *Pilot Testing: Music Selection*

In order to select a music track that was likely to be generically considered subjectively arousing yet pleasant[1], a sample of 73 sports science undergraduates was recruited; 39 were male and 34 were female. Participants' ages ranged from 18 to 31 years (M = 19.9 years, SD = 2.2 years). Fifty-two participants described their ethnicity as *White UK*; the remaining 21 participants' ethnicities comprised the following: *Black UK*, *African*, *African English*, *Asian UK*, *Chinese*, *Italian*, *Middle Eastern*, *Mixed Race*, *Moroccan*, *Other Mediterranean*, *Somalian*, *White Irish*, *White Mixed*, and *White Portuguese*. Participants' full demographic details can be found in Appendix S.

One-minute excerpts of 20 researcher-selected music tracks stored in digital format were played to participants via a lecture theatre integrated audio system; the tracks collectively represented a variety of musical genres, comprising *Dance*, *Blues*, *House*, *Punk Rock*, *Opera*, *New Age*, *Classical*, *Romantic*, and *Country Rock*. Some tracks were specifically selected because they were deemed likely to be considered pleasant and arousing, both of which partly determined by prior exposure (Peretz, Gaudreau et al., 1998) and a combination of intrinsic and extrinsic sources of emotion (Bishop et al., in press). The genres of these selected tracks repeatedly occurred in participants' selections in Chapter 3 of the present research programme. Others were deliberately chosen to represent genres which did not appear in these selections, so as to contemporaneously lend further validation of the efficacy of the Affect Grid in measuring both the pleasantness and arousal dimensions of emotional responses to music; this music was likely to be associated with low valence. All

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[1] This latter quality was retained in order to maintain some degree of ecological validity (music tracks perceived as pleasant are more likely pre-performance selections (Bishop et al., in press). Also, positive affect appears to be associated with increased motor activity (Ashby et al., 1999).

participants were instructed to record their emotional response to the track after 45 s of listening, on a customised record sheet comprising 20 small reproductions of the Affect Grid (Russell, Weiss et al., 1989). Participants' mean Affect Grid responses to the tracks are shown in Table 6.1, and are graphically depicted in circumplex space in Figure 6.2. *Pump It*[2] by *The Black Eyed Peas* emerged as the most arousing and most pleasant track, on average; it also exhibited a fast tempo (150 bpm). Therefore, it was decided that this track would be used in the main study.

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[2] Released in the UK on 28 February 2006, on the A&M/Interscope record label; peak UK chart position of 3. Genre(s): *Hip-hop/R'n'B/Pop*.

Table 6.1

Pilot Group Affect Grid (Russell, Weiss et al., 1989) Ratings for Selected Tracks

Track (Artist; tempo [bpm])	Pleasantness		Arousal	
	M	*SD*	*M*	*SD*
Can't Get Enough (Soulsearcher; 130)	5.52	1.98	5.34	1.89
Dance With My Father (Luther Vandross; 84)	6.18	2.35	2.86	1.44
Digging My Potatoes (Big Bill Broonzy; 72)	4.27	2.23	2.77	1.37
If I Had My Way I'd Tear the Building Down (Blind Willie Johnson; 85)	2.97	1.84	2.77	1.63
Insomnia (Faithless; 132)	5.45	2.32	5.49	2.42
Irresponsible Hate Anthem (Marilyn Manson; 186)	1.74	1.08	6.58	2.28
Jump Around (House of Pain; 110)	6.44	1.67	7.38	0.91
Love Don't Let Me Go (David Guetta vs. The Egg; 130)	6.82	2.06	7.33	1.70
O Mio Babbino Caro (Maria Callas; 66)	5.45	2.51	2.86	1.93
Orinoco Flow (Enya; 60)	5.82	1.90	3.03	1.38
Piano Concerto No. 2 in F Minor (Frédéric Chopin; 48)	5.73	1.94	1.88	1.18
Pump It (The Black Eyed Peas; 150)	7.04	1.26	7.51	1.00
Put Your Records On (Corinne Bailey Rae; 102)	7.03	1.34	4.04	1.48
Rock Is Dead (Marilyn Manson; 138)	2.67	1.69	6.37	1.77
The Fight Song (Marilyn Manson; 132)	2.22	1.57	7.03	1.92
The Nobodies (Marilyn Manson; 78)	3.11	1.87	5.1	1.76
The Old Country Church at the Foot of the Hill (The Johnson Family Singers; 90)	3.55	2.13	3.08	2.06
This is the New Shit (Marilyn Manson; 96)	2.15	1.49	7.08	1.86
When I Got Troubles (Bob Dylan; 94)	4.48	2.38	2.66	1.51
Workingman's Blues #2 (Bob Dylan; 74)	4.33	2.35	2.55	1.34

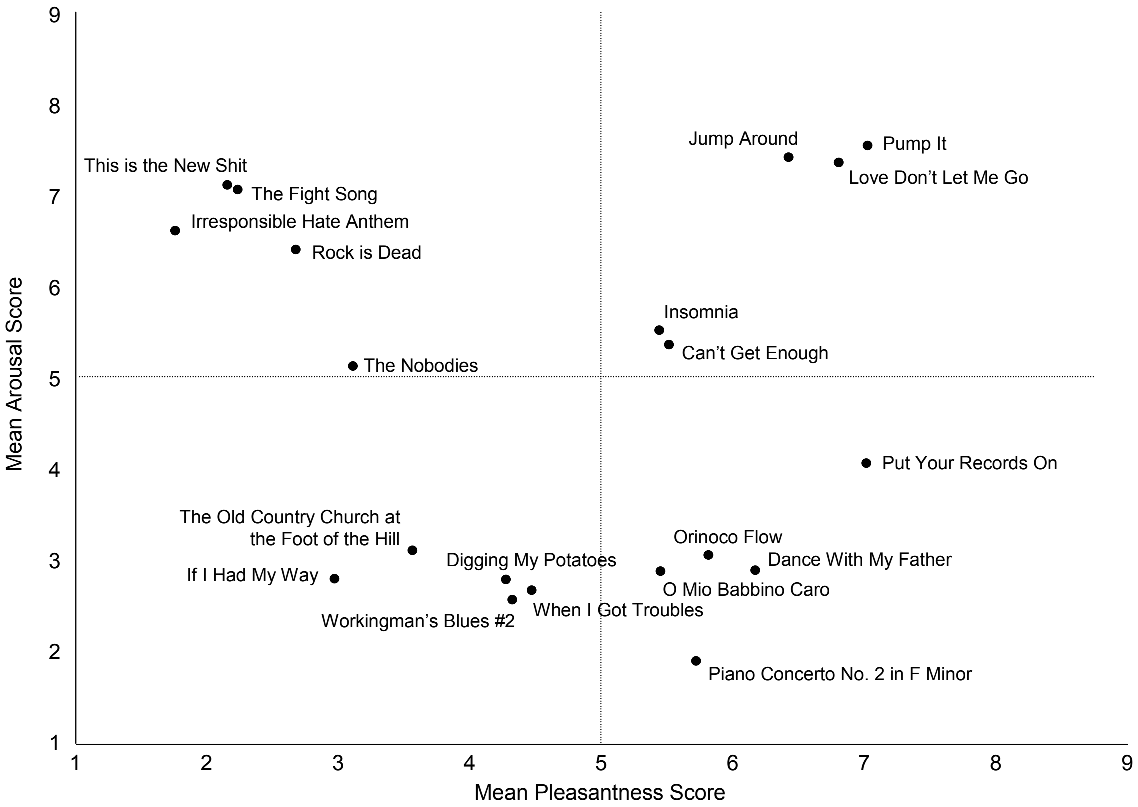

Figure 6.2. Circumplex model distribution of Affect Grid (Russell et al., 1989) ratings for pilot study tracks.

6.4.2 *Correlation Analysis of Ratings and Tempi for Pilots Tracks*

Pleasantness was neither correlated with arousal, $r(20) = -.17, p > .05$; nor tempo, $r(20) = -.10, p > .05$. However, arousal and tempo exhibited a strong positive correlation, $r(20) = .78, p < .01$.

6.4.3 *Sample Size Estimation*

Because self-reported arousal appears to be a good reflection of autonomic nervous system arousal (Baumgartner et al., 2007) and EEG activity (Kallinen & Ravaja, 2004) as a result of listening to music, mean Affect Grid (Russell, Weiss et al., 1989) arousal scores from Chapter 4 were entered into power analysis software (GPower, Faul, & Erdfelder, 1992) in order to determine a suitable sample size for the main study. The means for *fast loud music* (6.57) and *silence* (2.94) conditions, together with their pooled standard deviation (2.13), were entered into GPower’s effect size calculation tool, to calculate Cohen’s (1988) *d*; the returned value was 1.70. This was entered into GPower's sample size calculation tool, together with an alpha level of .05; a desired power of .7 was specified. A required sample size of 10 was returned by the software program.

6.4.4 *Participants*

An international junior tennis centre in southwest London, England, UK, catering to young tennis players from a wide variety of sociocultural backgrounds, was chosen as a suitable site for data collection. All participants were volunteers, and comprised 10 full-time tennis players, eight male and two female; more participants could not be recruited to guard against experimental mortality and deletions caused by multiple univariate and multivariate outliers, due to time constraints. Participants' ages ranged from 18 to 31 years (M = 23.0, SD = 4.5 years). Seven participants described their ethnicity as *White UK*; of the remaining three participants, one was French and two were Ukrainian. All participants trained full-time (20 or more hours of tennis per week), and their experience of competitive tennis ranged from 84 to 168 months (M = 138.0, SD = 38.9 months). LTA Ratings[3] ranged from 1.1 (world ranked) to 5.1 (lower division county player); the median rating was 2.2 (world ranked, national standard, and/or top division county player), while the mode rating was 2.1 (world ranked, national standard, and/or top division county player). All participants were right-handed. Participants' full demographic details can be found in Appendix T.

6.4.5 *Equipment and Materials*

6.4.5.1 *Music delivery*. The selected music track was electronically stored on a laptop computer (HP Pavilion zx5275; Hewlett Packard, Palo Alto, CA) and played at 75 dBA on a continuous loop (with a 6 s crossfade) via a pair of earbud-type earphones (Creative EP-630; Creative Labs, Inc., Milpitas, California), which were plugged into a home stereo unit

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[3] Please refer to the LTA website (www.lta.org.uk) for guidance on LTA Ratings.

(Goodmans MS 355; Goodmans Industries Ltd., Portsmouth, UK) to allow amplification of the audio signal from the laptop computer headphone socket.

6.4.5.2 *EMG signal acquisition*. Two bipolar surface electrodes (Goldy Karaya Gel electrodes; silver/silver chloride; Arbo®, Henley Medical, Stevenage, UK) were attached at a spacing of 4 cm to the front of the participant's right (dominant) arm such that the central lead point was one-third of the distance from the biceps brachii (BB) tendon in the cubital fossa to the acromion (see Zipp, 1982), in order to record electromyographic activity; a ground electrode was attached to the ulnar olecranon of the same arm. The BB was chosen as a suitable muscle for detection of action potentials because of its strong corticospinal innervation, size and superficial location on the front of the upper arm, all of which reduce the likelihood of crosstalk interference from non-active muscles (e.g., brachialis); it was also the prime agonist for the movement required in the ensuing choice reaction time task.

Electromyographic signals were transduced via an adapter box (CED 1902-11/4; Cambridge Electronic Design, Cambridge, UK) into a preamplifier (CED 1902 amplifier; Cambridge Electronic Design, Cambridge, UK), where the signal was amplified by a magnitude of 1000 times. Signal noise was attenuated using a band pass filter of 20 Hz – 2 kHz and the remaining signal was digitized at a sampling rate of 4 KHz, using an analogue to digital converter (Micro1401; Cambridge Electronic Design, Cambridge, UK); this signal was acquired and later analyzed using sweep-based data acquisition and analysis software (Signal v. 2.09; Cambridge Electronic Design, Cambridge, UK) installed on a personal laptop computer (Packard Bell Easy One 1551; Packard Bell BV, Wijchen, The Netherlands). The beginning of a 0.8 s data acquisition period for each RT trial was initiated by an analogue audio trigger whose onset was synchronized with visual target stimulus onset; this trigger inputted directly from the headphone socket of the laptop computer to the trigger input terminal of the preamplifier. Software parameters were specified such that a pre-trigger period of 0.2 s was recorded.

6.4.5.3 *Transcranial magnetic stimulation (TMS)*. Monophasic output pulses were generated by a magnetic stimulator (Magstim 200; The Magstim Company Limited, Whitland, Wales) and delivered transcranially via a 70 mm double circular coil (The Magstim Company Limited, Whitland, Wales; see Figure 6.3) with a peak magnetic field strength of 2.2 Tesla and peak electric field strength of 660 V/m. The resultant motor evoked potential (MEP) was recorded at the BB.

Figure 6.3. A 70 mm double circular coil used to deliver monophasic magnetic pulses.

6.4.5.4 *Measurement of affective responses*. Participants recorded their affective responses to music by marking a cross in one box of a laminated version of the Affect Grid (Russell, Weiss et al., 1989), using a whiteboard marker. Participants also indicated their affective state by circling adjectives laid out in a grid formation on a laminated sheet (see Appendix H). There were 28 of these affective descriptors in total, identical to those used by Russell (1980).

6.4.6 *CRT Task*

The study design was created and executed, and RT data recorded, using experiment generator software (E-Prime v.1.1.4.1; Psychology Software Tools, Inc., Pittsburgh, Pennsylvania, US). Visual stimuli (see Figure 4.2) were presented using a laptop computer (HP Pavilion zx5275; Hewlett-Packard, Palo Alto, CA) widescreen display monitor. Participants' response options are identical to those detailed in Section 4.4.4. The buttons were equidistantly spaced 4 cm apart on a tabletop which stood 73 cm from the floor immediately in front of the seated participant (see Figure 6.4). Participants were afforded one block of 30 trials as practice.

6.4.7 *Determination of Optimal Cortical Activation Site*

Prior to beginning the experimental protocol, a mapping procedure was carried out to establish the optimal cortical site for activation of the BB, using anatomical landmarks of the International 10-20 system (Jasper, 1958). The sagittal plane was defined using a flexible tape measure extending from the nasion (the depression at the top of the nose) over the top of the head to the inion (the prominence in the midline at the base of the occiput); a line 3 cm in length was drawn at the approximate midpoint of this line. The coronal plane was defined as a straight line traversing the midpoint of the sagittal line, from a point immediately anterior to the tragus of one ear to the equivalent contralateral location. The intersection of the halfway points of these lines was designated as the vertex (locus *Cz* of the 10-20 system), and was subsequently marked on the participant's scalp. A point approximately 4.67 cm lateral to, and 0.44 cm anterior to, the vertex (values taken from Verhagen Metman, Bellevich, Jones, Barber, & Streletz, 1993) was used to initially orient the coil over the approximate location of motor cortex representation of the BB. The coil was moved alternately in 0.5 cm increments along both sagittal and coronal planes until a point was established whereupon magnetic stimulation yielded marked BB MEPs. This point was mapped with indelible ink to facilitate replicable application of pulses across trials.

6.4.8 *Procedure*

A repeated-measures design was employed wherein participants completed all conditions. The study was conducted in an air-conditioned and carpeted room with neither external walls nor opening windows. Thus, the room was relatively acoustically hermetic. After reading the Participant Information Sheet (see Appendix N), the participant was informed of what would be expected of them, and were invited to voice any queries. Once all questions had been answered to the participant's satisfaction and they had given their informed consent, the following protocol was performed three times for each of three conditions: *Baseline*, *silence*, and *music*. The *baseline* condition was completed first, because it was deemed likely that the procedure – which was novel to all participants – may be sufficiently exciting to elicit changes in participants' affective ratings and corticospinal excitability. The order of *silence* and *music* conditions was counterbalanced across all participants, to control for order effects.

6.4.8.1 *Registering of affective responses*. The participant sat in a chair facing the monitor display, and placed the earphones in their ears (Figure 6.4). The participant either sat in silence (*baseline* or *silence* conditions) or heard the selected music track (*music* condition). After 45 s had elapsed[4], the researcher prompted the participant to place a cross in a box of the Affect Grid (Russell, Weiss et al., 1989); the accompanying written instructions were as follows: *Please place a cross in ONE square to rate how you feel RIGHT NOW*. The researcher also prompted the participant to circle as many descriptors from the list of 28 words (cf. Russell, 1980) as they wished, to most accurately describe their affective state; the accompanying instructions for the descriptors read as follows: *Please circle any words from*

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[4] Koelsch et al.'s (2006) neurophysiological study of emotional responses to music showed that such responses are significantly greater in the second of two 30 s listening blocks.

the following list that describe how you feel RIGHT NOW. You may feel NONE of them; this is fine.

6.4.8.2 *Determination of motor threshold, MEP amplitude and latency*. After a further 45 s had elapsed, five monophasic pulses were delivered at an initial stimulus intensity of 100% of maximum. If motor threshold was reached at this point – a likely occurrence – stimulations were delivered in accordance with the following protocol: The intensity of stimuli was decreased at 5% intervals until reaching an intensity which failed to induce responses of approximately 100 μV (0.10 mV) in magnitude, in 3 of 5 consecutive trials; this criterion for motor threshold is similar to that used in previous research (e.g., Reutens & Berkovic, 1992). The term motor threshold is used herein to describe this phenomenon because the changes in responsiveness witnessed can reflect motor neuron excitability, cortex excitability, or both (Mills, 1999). In order to measure MEP amplitude and latency, the stimulus intensity was set at 120% of motor threshold. Mean values were calculated from the averaged response of five MEPs.

6.4.8.3 *CRT task performance and EMG recording*. After the participant had listened to the track and recorded their affective responses, and their motor threshold had been determined, a third screen appeared, which displayed the following instructions: *Please get ready to respond to the dots on the screen: LEFT for a dot on the LEFT, CENTRE for a dot in the CENTRE, RIGHT for a dot on the RIGHT, Your hand must always begin with the palm facing down on your thigh* (such a supported, pronated forearm position served to reduce unwanted BB activity). The participant then responded as quickly as possible to each of 30 trials (10 x 3 alternatives) presented in a software-generated randomized order, by striking the corresponding button as quickly as possible. Each trial was preceded by a reminder screen reading *Palm face down*, and then a screen depicting a blank court preceded each stimulus, for 1 s duration. Target stimuli moved on once a participant's response had been registered, or after 1 s in the event of a movement error. During this period, the researcher logged the participant's affective responses on the participant's study record sheet; EMG data were recorded automatically by the data acquisition software (Signal v. 2.09, Cambridge Electronic Design, Cambridge, UK). This procedure was repeated for each of the three experimental conditions.

Figure 6.4. A participant listening to a music track immediately prior to providing affective data.

6.4.9 *Data Analysis*

6.4.9.1 *Motor threshold, MEPs and CRT task EMG*. Individual motor thresholds were determined as described above. Peak-to-peak amplitude and latency of the evoked responses during both motor threshold determination and CRT task EMG recording were measured using the data analysis software (Signal v. 2.09; Cambridge Electronic Design, Cambridge, UK) graphical user interface. Latency was defined as the time elapsed between onset of the stimulus (whether magnetic pulse or visual target) and the onset of the response, namely, the first notable departure of the waveform from the baseline signal. Peak-to-peak amplitude was measured from peak to trough by placing cursors so as to encompass these points; use of the data analysis software enabled calculation of peak-to-peak amplitude, in millivolts. Figure 6.5

depicts the waveform landmarks used for a typical MEP. All EMG data were convolved for each condition to give a mean value. The EMG signal was analysed in the time domain, and the peak-to-peak amplitude was calculated automatically by the data analysis software.

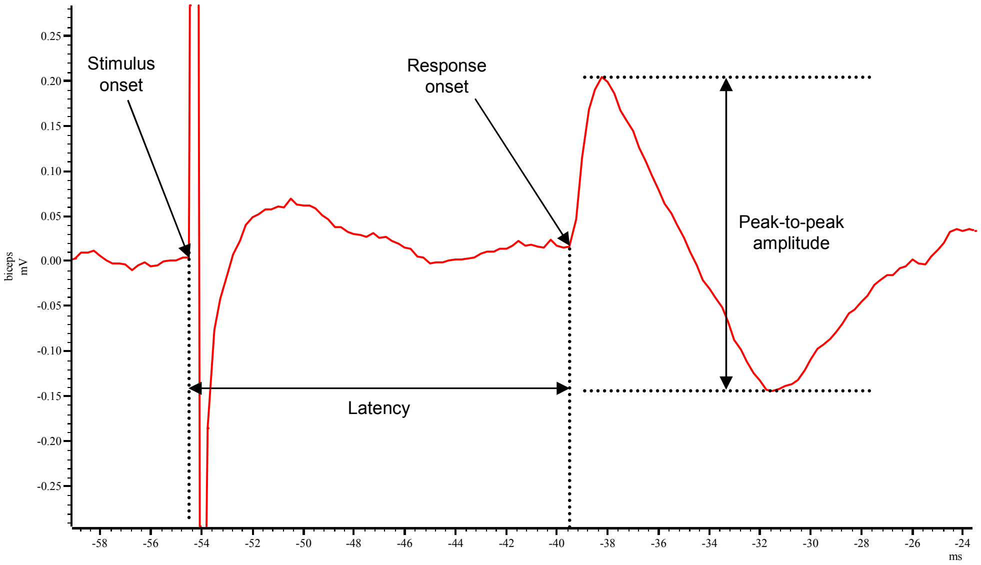

Figure 6.5. Illustration of one participant's averaged waveform landmarks used for MEP data analysis (graphics superimposed on a screenshot from the graphical user interface of Signal v. 2.09 software, Cambridge Electronic Design, Cambridge, UK).

6.4.9.2 *RT data*. RT data were imported into a software package which enables grouping of participants' individual E-Prime data (E-DataAid v.1.1.4.1; Psychology Software Tools, Inc., Pittsburgh, Pennsylvania, US). Participants' error rates during response to experimental stimuli were negligible (0.29%), and these data were therefore automatically excluded from the analysis using E-DataAid's *Filter* option. Grouped data were analysed using statistical analysis software (SPSS 13.0 for Windows, SPSS Inc., Chicago, IL, US).

6.4.9.3 *Affective data*. Affect Grid (Russell, Weiss et al., 1989) ratings were transferred to a workbook in spreadsheet software (Microsoft Excel 2002; Microsoft Corporation, Fargo, ND, US), before transfer to statistical analysis software (SPSS 13.0 for Windows; SPSS Inc., Chicago, IL, US). Adjectives were grouped according to condition for content analysis.

6.5. Results

6.5.1 *Qualitative Data Analysis*

The descriptors provided by participants exhibited a varied distribution across all conditions (Table 6.2), although there was a slight trend towards the selection of adjectives used to describe varying degrees of pleasure (*delighted*, *excited*, *satisfied*, *pleased*) and a perceived reduction in fatigue (*tired*, *sleepy*) when listening to music. None of the participants recorded experiencing any of the following descriptors, from Russell's (1980) original study: *Astonished*, *angry*, *annoyed*, *distressed*, *miserable*, *sad*, *gloomy*, *depressed*, *bored*, *droopy*, and *glad*. They were therefore not included in Table 6.2.

Table 6.2

Content Analysis of Descriptors, by Condition

	Condition		
Descriptor	Baseline	Silence	Music
Happy	7 (46.67%)	2 (13.33%)	6 (40.00%)
Delighted	0 (0.00%)	0 (0.00%)	3 (100.00%)
Excited	1 (12.50%)	1 (12.50%)	6 (75.00%)
Aroused	0 (0.00%)	2 (50.00%)	2 (50.00%)
Tense	0 (0.00%)	2 (100.00%)	0 (0.00%)
Alarmed	0 (0.00%)	1 (100.00%)	0 (0.00%)
Afraid	0 (0.00%)	1 (100.00%)	0 (0.00%)
Frustrated	0 (0.00%)	1 (100.00%)	0 (0.00%)
Tired	4 (66.67%)	2 (33.33%)	0 (0.00%)
Sleepy	2 (50.00%)	2 (50.00%)	0 (0.00%)
Calm	5 (50.00%)	4 (40.00%)	1 (10.00%)
Relaxed	5 (35.71%)	4 (28.57%)	5 (35.71%)
Satisfied	2 (28.57%)	1 (14.29%)	4 (57.14%)
At ease	1 (11.11%)	4 (44.44%)	4 (44.44%)
Content	5 (45.45%)	4 (36.36%)	2 (18.18%)
Serene	1 (33.33%)	1 (33.33%)	1 (33.33%)
Pleased	0 (0.00%)	3 (42.86%)	4 (57.14%)

6.5.2 *Quantitative Data Analysis*

6.5.2.1 *Missing data*. Participant 1 did not wish to be subject to TMS, and therefore did not contribute motor threshold or MEP data. In order to yield equal cell sizes for each portion of the analysis, non-missing data for all conditions and all participants (including those of Participant 1) were entered as predictor variables into an Expectation-Maximisation algorithm used to predict the missing values; this was implemented using statistical analysis software (SPSS 13.0 for Windows; SPSS Inc., Chicago, IL, US). The mean values generated were subsequently used in the main analysis.

6.5.2.2 *Outliers and normality*. Checks for outliers revealed no univariate or multivariate outliers. Tests of the distribution of data in each cell of the analysis revealed slight violations of normality: Baseline data for MEP latency were positively skewed ($p < .05$) and leptokurtic ($p < .01$); and baseline data for CRT Task EMG amplitude were positively skewed ($p < .05$). Table 6.3 displays descriptive data for all DVs. Because violation of the analysis of variance (ANOVA) assumption of normality does not radically change the F value (Vincent, 2005), and because the violations were not due to outliers (Tabachnick & Fiddell, 2006), the F test was retained as the test of significance.

6.5.2.3 *Correlation analysis of dependent variables (DVs)*. All DVs were entered into a correlation analysis, to determine their interrelationships. These data are displayed in Table 6.4.

6.5.3 *Main Effect of Condition*

Examination of Table 6.4 reveals a mixture of both correlated and uncorrelated DVs. Tabachnick and Fiddell (2006) recommend that separate MANOVAs run on sets of moderately correlated DVs are likely to yield the most interesting interpretations (p. 357), but further examination of Table 6.4 reveals no discernible patterns to the correlations therein. Therefore, a MANOVA on all DVs was considered the most parsimonious approach. Pillai's

Trace was chosen as the omnibus statistic to report, because of its robustness in relation to both a comparatively small size, and violation of the assumption of homogeneity of variance-covariance matrices. The main effect for condition was significant, $F(16, 24) = 2.22$, $\eta_p^2 = .60$, $p < .05$. Follow-up pairwise comparisons were conducted to examine differences between the conditions for each of the eight dependent variables: *Arousal score*, *pleasantness score*, *reaction time*, *motor threshold*, *MEP amplitude*, *MEP latency*, *CRT Task EMG amplitude*, and *CRT Task EMG latency*. Mauchly's Test of Sphericity showed that data for the following DVs had violated the sphericity assumption: *Arousal score*, Mauchly's $W(2) = .43$, $\chi^2 = 6.85$, $p < .05$; *reaction time*, Mauchly's $W(2) = .41$, $\chi^2 = 7.10$, $p < .05$; *MEP latency*, Mauchly's $W(2) = .04$, $\chi^2 = 25.63$, $p < .001$; and *CRT Task EMG amplitude*, Mauchly's $W(2) = .06$, $\chi^2 = 23.08$, $p < .001$. Therefore, a Greenhouse-Geisser adjustment was applied to these data only.

6.5.3.1 *Post hoc tests*. Follow-up multiple comparisons with Bonferroni adjustment indicated that arousal scores were significantly higher on listening to music ($M = 7.40$, $SD = 1.17$) when contrasted with baseline values ($M = 4.50$, $SD = 1.90$), $F(1.27, 11.43) = 10.84$, $\eta_p^2 = .55$, $p < .01$ (95% confidence interval: Lower boundary = .74; upper boundary = 5.06). CRT Task EMG latency was also reduced after listening to music ($M = 77.39$, $SD = 33.84$), when contrasted with baseline ($M = 101.42$ ms, $SD = 16.00$), $F(1.52, 13.64) = 6.80$, $\eta_p^2 = .43$, $p < .05$ (95% confidence interval: Lower boundary = .61 ms; upper boundary = 47.45 ms). These data are depicted in Figure 6.6.

Table 6.3

Descriptive Statistics and Univariate Statistics for all DVs

Dependent Variable	Condition	*M*	*SD*	Std. skew.	Std. kurt.
Arousal score	Baseline	4.50	1.90	-0.80	-0.50
	Silence	6.50	1.35	-0.73	-0.35
	Music	7.40	1.17	-0.69	0.77
$F(1.27, 11.43) = 10.84$, $\eta_p^2 = .55$, $p < .01$					
Pleasantness score	Baseline	6.70	1.25	1.03	-0.37
	Silence	6.50	1.18	-0.37	-1.08
	Music	7.40	0.84	0.57	0.28
$F(2, 18) = 2.13$, $\eta_p^2 = .19$, $p > .05$					
Reaction time (ms)	Baseline	416.33	44.13	0.93	-0.72
	Silence	411.32	33.77	-0.53	-0.98
	Music	398.95	34.82	0.51	-1.11
$F(1.26, 11.33) = 2.26$, $\eta_p^2 = .20$, $p > .05$					
Motor threshold (% of maximum intensity)	Baseline	70.87	14.59	-1.07	1.03
	Silence	71.24	18.74	0.19	-0.40
	Music	69.22	14.73	0.55	0.28
$F(2, 18) = .35$, $\eta_p^2 = .04$, $p > .05$					

(*table continues*)

Table 6.3 (continued)

Dependent Variable	Condition	*M*	*SD*	Std. skew.	Std. kurt.
MEP Amplitude (mV)	Baseline	0.22	0.12	1.91	1.27
	Silence	0.20	0.10	0.22	-0.91
	Music	0.22	0.11	0.66	-0.50
$F(2, 18) = 0.34$, $\eta_p^2 = .04$, $p > .05$					
MEP Latency (ms)	Baseline	14.06	3.93	2.49^{*}	2.88^{**}
	Silence	12.51	2.18	0.43	-0.96
	Music	11.80	3.07	-0.63	0.31
$F(1.01, 9.12) = 1.55$, $\eta_p^2 = .15$, $p > .05$					
CRT Task EMG Amplitude (mV)	Baseline	0.09	0.05	1.99^{*}	1.76
	Silence	0.09	0.05	0.61	-0.53
	Music	0.39	0.47	1.51	-0.61
$F(2, 18) = 4.65$, $\eta_p^2 = .34$, $p > .05$					
CRT Task EMG Latency (ms)	Baseline	101.42	16.00	-0.81	-0.06
	Silence	101.42	16.00	-0.90	0.81
	Music	77.39	33.84	-0.57	-0.81
$F(1.52, 13.64) = 6.80$, $\eta_p^2 = .43$, $p < .05$					

Note. Std. skew. = standard skewness; Std. kurt. = standard kurtosis.

* $p < .05$. ** $p < .01$.

Table 6.4

Bivariate Correlation Coefficients of Dependent Variables

	1	2	3	4	5	6	7	8
1. Arousal score	1.00							
2. Pleasantness score	-0.07	1.00						
3. Reaction time	-0.17	-0.09	1.00					
4. Motor threshold	0.02	0.10	0.50^{**}	1.00				
5. MEP amplitude	-0.11	-0.16	-0.44^{*}	-0.85^{**}	1.00			
6. MEP latency	0.00	-0.20	0.39^{*}	0.06	-0.02	1.00		
7. CRT Task EMG amplitude	0.43^{*}	0.32	-0.30	-0.24	0.06	-0.30	1.00	
8. CRT Task EMG latency	-0.40^{*}	-0.08	0.55^{**}	0.17	-0.20	0.29	-0.56^{**}	1.00
M	6.13	6.87	408.87	70.44	0.21	12.81	0.19	94.26
SD	1.91	1.14	37.28	16.47	0.11	3.34	0.30	30.13

* $p < .05$. ** $p < .01$.

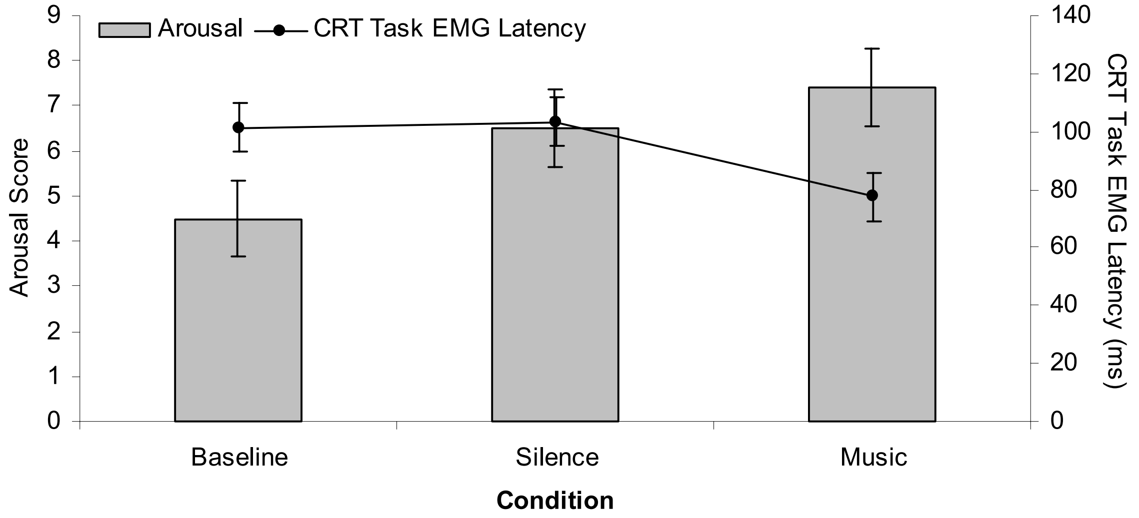

Figure 6.6. Mean arousal scores and CRT task EMG latencies, by condition.

6.6 Discussion and Conclusions

6.6.1 *Overview*

The results provide partial support for the experimental hypotheses, and for previous studies which have demonstrated an improvement or increase in motoric output as a result of listening to music (Anshel & Marisi, 1978; Atkinson et al., 2004; Elliott et al., 2003; Karageorghis et al., 1996). The music condition was rated as significantly more arousing than baseline ($p < .01$), although ratings were not significantly higher than those for the silence condition. Corticospinal excitability was not significantly different across conditions during listening. However, the means for motor threshold and MEP latency were lower and shorter, respectively, for the music condition when contrasted with both baseline and silence conditions, and average MEP amplitude was higher for the music when contrasted with silence. Unlike previous studies examining relationships between music listening and corticospinal excitability (e.g., Baumgartner et al., 2007; Wilson & Davey, 2002), the present study also examined the effects of music listening on EMG activity after cessation of the music; the latency of in-task EMG during CRT performance trials was significantly shorter than for silence and baseline conditions ($p < .05$). In-task EMG amplitude only approached significance ($p = .058$), despite the mean value being over fourfold higher than both baseline and silence conditions; the lack of statistical significance can be explained in part by the large variability in scores in this condition when compared to those for baseline and silence (SD = 0.47 and 0.09 respectively). Reaction times were not significantly different but, importantly, mean values were again in the predicted direction: Reaction times were 3% and 4% shorter in the music condition than in the silence and baseline conditions respectively.

Some justification was found in the correlational analysis, for (a) the use of the three measures of corticospinal excitability, and (b) the rationale of the present study. Motor threshold and MEP amplitude correlated very strongly, suggesting that they were both tapping the same underlying phenomenon (corticospinal excitability) although MEP latency exhibited near-zero correlations with both. Importantly, reaction times displayed moderate correlations with each of the three aforementioned measures, suggesting that corticospinal excitability may indeed be a key factor in determining overall reaction time.

Further justification for the predictive value of the circumplex model was yielded in the pilot phase of the present study. Figure 6.2 depicts that, collectively, the 20 tracks selected by the researcher are evenly distributed throughout each of the four quadrants of the circumplex model. This provides some evidence that it is possible to reasonably accurately select music for a given sample of participants with the aim of inducing a desired emotional state, when armed with a priori knowledge of demographics such as age, athletic prowess, and gender; this was the case in the present study.

6.6.2 *The Role of Tempo*

There is a tendency for human beings to coordinate their movements with the musical beat, described by Karageorghis et al. (1999) as the *rhythm response*; this phenomenon has since been shown to impact on cycle ergometer performance (Karageorghis, 2000). This assertion is also supported by physiological evidence; for example, that heart rate tends to be closely related to the tempo of music heard (e.g., Iwanaga, 1995). In music emotion research, faster tempi have typically been associated with happier or more positive affective responses (Dalla Bella et al., 2001; Webster & Weir, 2005). In the present study, tempo exhibited a strong positive correlation with the arousal potential of the tracks heard in the pilot phase, $r(20) = .78$, $p < .01$, but was not correlated with pleasantness ($p > .05$); a finding which corroborates the conclusions drawn earlier in the present research programme. However, this may simply highlight the interaction of both extrinsic and intrinsic sources of emotion: A number of the pilot tracks were purposively selected because they were very likely to be completely unfamiliar to the participants, and they were also from a genre which was unlikely to be popular with these participants – who were demographically comparable to the intended main study sample. Thus, the likelihood of the tempo variable overriding these sometimes potent extrinsic sources of emotion (cf. Rickard, 2004) was slight.

6.6.3 *The Role of Extrinsic Sources of Emotion in Eliciting Responses*

The contribution of extrinsic sources to musically-induced emotional states was not assessed in the present study. The selected track was rated by pilot participants as being subjectively arousing, whilst the researcher-selected track used in the previous two studies of the present research programme, *Deepest Blue*, had not been through such a screening process; in fact, it was purposely selected because it would be familiar yet not overly popular. During the piloting phase there was a perceptible alteration in the motor behaviour (e.g., fidgeting) of the participants in response to the track *Pump It*. The tempo of this track could not by itself explain the high arousal scores yielded; one of the pilot tracks was faster, and three additional pilot tracks satisfied Gaston's (1951) qualifying criteria to be classified as *stimulative*. Therefore, the high arousal scores might have been due to a number of extrinsic factors. For example, the music video for this track contains an opening scene of a fast hatchback car containing members of the *Black Eyed Peas* moving at a frenetic speed through an underground car park, before screeching to a halt. There follows an energetic and confrontational dance-off between the group members, their cronies, and another group who had been waiting in the car park. The dancing is energetic and provocative – in both sexual and aggressive terms. Given the prevalence of music video use by young athletes (Bishop et al., in press), it is conceivable that many of the participants in both the pilot and main phases of the present study had seen the video – which might have elicited stronger elicited emotional responses.

6.6.4 *Potential Mechanisms*

In light of the present findings, it is possible that music prompts more coordinated motor activity, rather than increasing motor activity per se. In the foregoing study, all music conditions combined elicited greater activation in the cerebellum than did silence; the cerebellum plays a major role in coordinating gross motor movements (Bear et al., 2007). For example, the ascending fibres from the cerebellum synapse on the vestibular nuclei in the medulla; the lateral vestibular nuclei begin the vestibulospinal tract, which facilitates activity in all extensor (anti-gravity) muscles, thereby promoting increased stability. This notion finds some support from the findings of Wilson and Davey (2002), who showed that listening to music with a strong rhythm tended to promote muscular activity peculiar to foot-tapping. Most importantly, MEPs measured in the gastrocnemius (a strong ankle extensor) were facilitated when TMS pulses were delivered during the beat, not in between beats. Thus, music with a strong beat, such as that used in the present study, may promote enhanced stability, and this may be achieved via cerebellum-driven recruitment of small motor units necessary for fine-tuning gross motor movements.

There was also further evidence that the emotional response to music is enduring, to corroborate Koelsch et al.'s (2006) neurophysiological data. Not only was the music condition considered significantly more arousing than the baseline condition, but arousal scores correlated positively and negatively with CRT task EMG amplitude and latency, respectively. However, arousal scores did not correlate whatsoever with either the amplitude or latency of MEPs elicited during the listening period. This may mirror Baumgartner et al.'s (2007) assertion that music listening alone increases vegetative arousal, but is not evaluated in such a self-referential way that a motivational approach system (e.g., Panksepp, 1998) is engaged. But when the residual arousal-oriented emotional response to the music was coupled with the evaluation of an external, personally significant, stimulus (i.e., the visual

CRT task stimuli), corticomotor excitability was increased. Therefore, a TMS measure during CRT task performance may be apposite. An affective measure taken immediately prior to task execution might have also revealed an even greater emotional response in terms of arousal and/or pleasantness, which represents a worthwhile consideration for future research.

6.6.5 *Limitations*

Many of the findings relating to corticospinal excitability were in the expected direction, but did not reach statistical significance. A larger sample might have yielded greater power, and therefore increased the likelihood of uncovering significant findings. However, the constraints of data collection were such that post hoc increase of the sample was not viable; a priori power analysis suggested that a sample size of 10 was sufficient in order to witness changes in subjective arousal. This was the case when compared to baseline values, but this heightened state of arousal was insufficient to elicit significant changes in all but in-task EMG latency. In future research efforts, a larger sample would deliver greater experimental power. For example, a sample of 14 participants would have afforded an experimental power of .9.

Data were collected for all three conditions on the same occasion, which served to equilibrate contextual features for each condition, but might have led to heightened corticospinal excitability post-baseline: The procedure was novel to all participants, and was approached with trepidation by some. Indeed, Participant 1 chose to abstain from this segment of the study because of such wariness. In light of the variability in corticospinal excitability in response to a variety of environmental stimuli (e.g., Cerqueira et al., 2006; Hess et al., 1986; Hollge et al., 1997), the TMS procedure might have been sufficiently arousing in itself – potentially exerting its greatest impact on the immediately ensuing condition. Given that music and silence conditions were counterbalanced, half of all participants partook in the silence condition immediately subsequent to the baseline condition, which might have accounted for the lack of significant differences in participants' arousal scores between music and silence conditions.

Emotional imagery has been shown to affect corticospinal excitability (Tormos et al., 1997). Also, excitability increases as reactive operation nears (Davey et al., 1998). Motor imagery also facilitates corticospinal excitability, in both hemispheres, although only left hemisphere displays such facilitation for both ipsilaterally and contralaterally imagined movements (Fadiga et al., 1999). Participants in the present study might not have exhibited significant preparatory activity in the premotor area during the listening period, because they were not specifically waiting to perform the reaction time task. However, participants were seated in front of the display screen, and were able to anticipate their involvement in the CRT task, which took place immediately subsequent to the delivery of TMS pulses. In order to control for the effects of emotive or task-related imagery, a *filler* task may be employed in future; examples of such fillers are backward counting and change detection tasks.

The coil used in the present study might not have represented the most efficient means by which to stimulate the human motor cortex. Thielscher and Kammer (2004) compared the electric field properties of the Magstim 70 mm double coil (as used herein) with those of the Medtronic MC-B70 double coil. Although the two coils exhibited similar focality values and stimulation depths, the Magstim coil was significantly less efficient than its Medtronic counterpart, meaning that the amount of induced electric field was higher in the latter for any given stimulus intensity. This difference might have been sufficient to yield very different measures of corticospinal excitability resulting from music listening.

6.6.6 *Future Research*

Certain aspects of personality seem to strongly mediate both affective and electrocortical components of emotional responses to music (Kallinen & Ravaja, 2004), and those described as *highly anxious* exhibit increased striate muscle activation in response to both anticipation and presentation of a stressful stimulus (Fridlund, Hatfield, Cottam, & Fowler, 1986). There is also evidence that traits related to extraversion can increase the response to music during performance of a muscular endurance task (Crust & Clough, 2006). Therefore, it would be prudent to examine the role of personality in determining corticospinal excitability as a result of listening to music, in future.

Although the present study has provided some evidence that moderate increases in corticospinal excitability occur as a function of music listening, and that this is related to subsequent CRT performance, it was not possible to indicate the precise locus of the increased excitability in the corticospinal pathways. For example, Mills (1999) noted that "A raised threshold might then represent relative inexcitability of the spinal motoneurons or could equally indicate reduced excitability of cortex. Conversely, a reduced threshold would indicate hyperexcitability at cord or cortex or both" (pp. 178-179). A potential solution to this issue would be for future researchers to examine the H-reflexes of spinal motor neurons, which would enable them to identify the relative contributions of cortical and spinal excitability to the global phenomenon. However, this procedure is considerably more invasive than those employed herein.

The present data are inconclusive, but it is tentatively proposed that increased corticomotor excitability may indeed be a causal factor in determining the performance-facilitating consequences of emotional responses to music. Music with faster tempi exert a beneficial effect on electrocortical indices of visual attention (Amezcua et al., 2005) when played concurrently; and greater activation inferior temporal gyrus is elicited during CRT task performance subsequent to listening to fast loud music (Bishop, Wright, & Karageorghis, 2007). It may be fruitful to examine the effect of listening to fast music on subsequent visual performance, by using an eye-tracking protocol in conjunction with fMRI and/or electrophysiological data, to determine the relative contributions of visual processing and motor function to the performance improvements witnessed previously (Bishop & Karageorghis, 2007).

Given the residual effects of emotional responses music witnessed both herein and in previous neurophysiological investigation (Koelsch et al., 2006), together with firm evidence for autonomic changes resulting from listening to music (e.g., Baumgartner et al., 2007; Khalfa, 2002; Krumhansl, 1997; Nyklícek et al., 1997), it would be prudent for future researchers to examine blood-borne markers of autonomic nervous system activity, such as acetylcholine and epinephrine. Opportunities for such interdisciplinary collaboration between psychologists and physiologists are on the increase, given the comparatively recent developments in technology.

6.6.7 *Summary*

Despite the majority of corticospinal excitability measures not reaching statistical significance, all changes were in the anticipated direction: Measures relating to the music condition displayed a trend towards higher corticospinal excitability than did those for a silence condition. Moreover, the results complemented both the extant data from this thesis and prior research (Koelsch et al., 2006) to conjointly demonstrate that an extended emotional response to music, which encompasses increased electrophysiological activation, is apparent. Explanations for the present findings can readily be couched within existing motivation-based theories of emotion (e.g., Gray, 1994; Lang, 1995; Panksepp, 1998): Heightened arousal resulting from emotional responses to music appears to heighten corticospinal activity, the cortical component of which is crucial in determining approach responses (Schiff & Bassel, 1996).

CHAPTER 7: GENERAL DISCUSSION AND CONCLUSIONS

The aims of this chapter are fourfold; namely, to (a) review the main objectives and findings of the present research programme, (b) discuss the implications of the work contained within this thesis, (c) propose a tentative mechanistic model of music use, and (d) outline recommendations for future research and practice.

7.1 Overview of Main Objectives

The primary aim of this thesis was to take a multicomponential approach to the examination of competitive tennis players' emotional responses to music, with the view that emotions are best defined by triangulating a combination of affective, physiological, behavioural, neurophysiological, and electrophysiological data (Figure 1.1). Triangulation of these data sources has become not so much a tactic for this author, more "a way of life" (Miles & Huberman, 1994, p. 267). Indeed, Panksepp (1998) noted that a comprehensive discussion of emotions must consider affective experience, behavioural/bodily changes, and neural circuitry information. To this end, a number of objectives were realised:

1. The examination of 14 young tennis players' current use of music to manipulate emotional state; this was done in order to better understand the relationships between antecedents of music use, mediators of the music selection process and music's effects, and self-reported or observable consequences of listening to music.
2. The development of a model of music which would (a) facilitate the work of researchers and practitioners wishing to examine or use music to manipulate athletes' emotional state, and (b) form a foundation for subsequent chapters in the present thesis.

3. The exploration of the relationship between affective responses to researcher-selected music and the behavioural consequences (i.e., CRT performance) using a controlled yet ecologically valid protocol.
4. A whole-brain examination of the neural mechanisms underlying any affective and behavioural changes witnessed in response to pre-performance music, as measured using functional magnetic resonance imaging (fMRI).
5. An elucidation of the impact of listening to music purposively selected according to pre-determined criteria on corticospinal excitability, using transcranial magnetic stimulation (TMS) and electromyographic (EMG) recording.

7.2 Summary of Main Findings

7.2.1 *A Grounded Theory of Young Tennis Players' Use of Music*

Qualitative and quantitative data in Chapter 3 collectively showed that young tennis players who use music as part of their pre-performance routine do so with the explicit or implicit aim of modulating their emotional state. Despite expectedly idiosyncratic music selections, in-depth analysis of the data elucidated five common goals associated with listening to music, which collectively represent emotion regulation: (a) to achieve an appropriate mental focus, (b) to increase confidence, (c) to attain a more positive mental state, (d) to psych-up, and (e) to relax. A diverse number of sources of emotion contributed to both the selection of music and the emotional responses; these sources can be delineated as both extrinsic and intrinsic in nature (cf. Sloboda & Juslin, 2001).

Extrinsic sources of emotion included extra-musical associations (Karageorghis et al., 1999), the role of parents and peers in the development of music preferences, film soundtracks and music videos, and identification with the artist and/or lyrics. Intrinsic factors predominantly comprised the acoustical properties of the music, such as bass, tempo, intensity (loudness), and melodic aspects. Measures based on Russell's (1980) circumplex model suggested that participants found all of their music selections both highly pleasant and highly arousing, but these tracks could be differentiated to a degree, according to two intrinsic sources of emotion: Intensity and tempo. Namely, those tracks purportedly used in order to psych-up exhibited markedly higher tempi and were played at a higher intensity by participants, when they were requested to select the intensity at which they would listen in order to attain the desired emotional state. This provided a suitable premise for the ensuing study. Ultimately, a model was developed to illustrate young tennis players' use of music to manipulate their emotional state. This model will serve as a platform for (a) practitioners wishing to utilise music more effectively in their interventions with athletes, and (b) researchers wishing to systematically examine athletes' emotional responses to music.

7.2.2 *Affective and Behavioural Consequences of Music Listening*

The results reported in Chapter 4 confirmed that emotional states could be significantly altered through manipulation of a researcher-selected track's tempo and intensity. This fact was borne out in multivariate analyses, which showed that faster tempi were associated with higher arousal, $F(1.76, 93.40) = 40.50$, $\eta_p^2 = .43$, $p < .001$, and pleasantness, $F(1.90, 100.90) = 10.03$, $\eta_p^2 = .16$, $p < .001$. Higher intensity was associated with higher arousal and shorter choice reaction times, $r(482) = –.14$. The selected music track, in all its forms, was considered more pleasant than white noise played at the same intensities, $F(5.52, 292.58) = 29.36$, $\eta_p^2 = .36$, $p < .001$, although loud white noise was considered more arousing than listening to the music track played at a slower tempo, $F(4.82, 255.37) = 24.06$, $\eta_p^2 = .31$, $p < .001$. There appeared to be an additive effect of intensity and tempo: Fast tempo music played at a loud intensity elicited significantly faster reaction times than did the same music played at a moderate intensity, $F(6.19, 328.22) = 2.34$, $\eta_p^2 = .04$, $p < .05$. Heart rate (HR) data did not differentiate emotional responses, possibly because the impact of the CRT task on HR superseded that of the music.

7.2.3 *Neurophysiological Indices of Emotional Responses to Music*

Neurophysiological data were obtained in Chapter 5, in order to elucidate the neural mechanisms that yielded the affective and performance changes witnessed in Chapter 4. Music elicited significantly greater activation in auditory cortex than did a period of silence. Auditory stimuli inducing a highly aroused state elicited significant activation in areas previously implicated in emotion processing (posterior cingulate and subcallosal cortex), sensorimotor/visuomotor integration (inferior parietal lobule and inferior temporal gyrus), and motor control (putamen) during performance of a post-music listening CRT task. This latter activation may be related to the intensity of the stimulus: Loud intensity stimuli elicited significantly greater activation in the putamen, also. Fast tempo also yielded greater inferior temporal gyrus activation than did music played at a slow tempo, both during listening and during subsequent CRT performance. Pleasant stimuli did not elicit activations in structures implicated in the processing of rewards, as in previous research (e.g., Blood & Zatorre, 2001; Koelsch et al., 2006; Menon & Levitin, 2005) when contrasted with unpleasant stimuli, but this was likely due to the relatively low unpleasantness of all unpleasant stimuli used. The sole activation from listening to more pleasant music was in middle frontal gyrus, an area which has been implicated in decision-making (Talati & Hirsch, 2005).

7.2.4 *Corticospinal Excitability Changes Resulting from Music Listening*

In Chapter 6, music was purposively selected (selection criteria were based on the foregoing findings) with the aim of eliciting an optimal emotional response for subsequent reaction time performance. Listening to a music track with a fast tempo played at a loud intensity induced somewhat durable emotional responses manifested in increased subjective arousal, and corticospinal excitability – as indicated by reduced latency of EMG response when performing a CRT task. Interestingly, CRT performance yielded music-silence differences of a similar magnitude to those observed in Chapter 4 but did not attain statistical significance, perhaps due to a considerably smaller sample size.

7.3 Implications of the Present Findings

The present thesis represents considerably more than an extension of previous work: A mechanistic overview of the link between music listening and subsequent performance has not been attempted before. The multicomponential data provided herein also give a greater insight than would be possible through one-dimensional analysis of emotional responses to music in tennis.

Music is used frequently by young people to increase their energy (Saarikallio & Erkkilä, 2007; R. E. Thayer, Newman, & McClain, 1994); and the present programme of research suggests that this activity is used by competitive tennis players (Chapter 3), and it is also productive – if energy is considered in terms of both subjective arousal and increased motor output. There was evidence for the functionality of music listening as an arousal increasing strategy, when compared to silence. However, despite further evidence that music successfully altered affective state (Chapters 3 and 4) and motor corticospinal excitability (Chapter 6), music per se did not elicit significantly higher activation than did silence in emotion-processing areas (Chapter 5). This is strong evidence for the need to consider the *present emotional state* and *desired emotional state* (Figure 3.2) of the listener in order to use music optimally; for example, silence might have afforded the participants time to engage in emotional imagery, leading to a neural response over-and-above that expected, thereby reducing the contrast.

7.3.1 *Sources of Musically-Induced Emotions*

One striking observation from the present thesis findings is the degree to which extrinsic sources contribute to musically-induced emotions. All participants in Chapter 3 rated their self-selected music – replete with potent extrinsic sources of emotion – as highly arousing and highly pleasant; the average ratings for all variants of the researcher-selected track used in Chapters 4 and 5 were somewhat lower, and the music track which had been purposely pre-selected for Chapter 6 using a pilot group demographically similar to those in the main study achieved moderately high ratings. Participants in Chapters 4 and 5 of the present research programme were highly unlikely to experience strong emotions with music that were similar to those described by Gabrielsson's (2001) participants; for example, because the music was researcher-selected and therefore lacked extra-musical associations. Expectedly, these were inherent in the self-selected music tracks used in Chapter 3.

Despite the highly idiosyncratic range of music preferences reported by participants in Chapter 3, it was deemed possible to examine an underlying commonality in order to examine the utility of music listening as a pre-performance strategy: Emotional responses. Therefore, Chapters 4 and 5 of this research programme were not ultimately concerned with the relationship between responses to the selected music track *Deepest Blue* itself and performance correlates, but between researcher-manipulated intrinsic sources of emotion – namely tempo and intensity – and the resultant emotion-mediated performance correlates. It became clear from a review of Chapter 3 quantitative data and existing research (Kellaris & Rice, 1993; Schubert, 2004; Szabo et al., 1999; Webster & Weir, 2005) that intensity and tempo were two easily manipulable music attributes which can exert potentially performance-enhancing effects on the listener's emotional state. There was encouraging evidence in Chapter 6 that, once these parameters had been optimised[1], the likelihood of superior performance is increased considerably; this was manifested in choice reaction times in which the magnitude differed as greatly between fast loud music and silence conditions as they did

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[1] This may refer to not only the intrinsic properties of tempo and intensity, but also extrinsic sources, which may also have contributed to the track's arousal potential.

in Chapter 4, a difference which would easily have attained statistical significance if the sample had also been of a comparable size.

There is considerable evidence that positively valenced musical stimuli elicit activation in neural structures which have been implicated in reward processing, such as the ventral striatum (Berridge, 2003; Esch & Stefano, 2004). For example, pleasant musical stimuli have consistently activated the nucleus accumbens, even when the music is researcher-selected (Blood & Zatorre, 2001; Brown et al., 2004). However, this music has been commonly contrasted with other auditory stimuli which would not likely be found on the iPod of a young athlete (e.g., a random concatenation of chunks of a music track). When considering Chapter 3 participants' frequent daily exposure to music video stations such as *MTV*, it becomes apparent that the tracks in an athlete's *pool of emotive music* are very likely to be in a state of constant evolution, and this is an important facet of emotion management with music: The constant exposure to popular music tracks afforded by a multitude of media sources renders music a Class B stimulus (cf. Colman et al., 1981); in other words, a stimulus to which exposure cannot easily be controlled. Thus, habituation to the stimulus is a likely outcome, which will diminish the listener's emotional response to the music. Therefore, consideration should be given to constant renewal of the athlete's music in order to maximise its emotional impact.

Affective data presented throughout this thesis suggest that music elicited an array of primary and secondary emotions, as measured in affective data throughout the programme. Primary and secondary emotions are comparable to Scherer's (2004) utilitarian and aesthetic emotions, respectively. Scherer noted that aesthetic emotions require some degree of appraisal of the eliciting stimulus in terms of its intrinsic artistic worth. However, participants were only required to elaborate upon the reasons for their music preferences in Chapter 3 – and this did not typically extend to a discussion of the intrinsic properties, due to participants' overall lack of musical expertise. The experimental paradigms used in the Chapters 4 and 5 afforded participants a lot of time to reflect on the properties of the music track, as they were exposed to six music blocks (of a total of nine) throughout both experimental protocols. Evidence also pointed to an interaction between tempo and intensity in determining behavioural outcomes (i.e., choice reaction time), and this was illustrated by the relative dearth of significant neural activations in both *loud-moderate* and *fast-slow* contrasts, when compared with those obtained from the *high arousal-low arousal* contrast. Now that the impact of music tempo and intensity on affective state and subsequent behaviour has been adequately elucidated, the research community is in a strong position to examine the impact of manipulating other sources of emotion – both intrinsic and extrinsic.

The appraisal of the relevance of a stimulus to one's wellbeing determines the action tendencies associated with that stimulus (Frijda et al., 1992), and emotions with strong action tendencies appear to have greater functionality in sport than do more traditional affective measures, such as anxiety (Cerin, 2003). The acoustical properties of music are indicative of some components of arousal; for example, faster tempo is reminiscent of an accelerated pulse, and research suggests that people naturally choose music tempi that reflect their current heart rate (Iwanaga, 1995a, 1995b; Karageorghis, Jones et al., 2006). Thus, appraisal of music with a fast tempo may lead to higher levels of arousal as a result. Perhaps faster tempi are simply indicative of greater vitality, which is a desirable state for the living organism, as it implies good health; this may be why they are generally considered more pleasant. Higher intensity represents, quite literally, a higher transfer of energy to the listener (see Section 5.6.2.2). If one accepts these underlying principles, it becomes straightforward to see why these two variables may contribute to the *iconic representation* of a highly aroused yet pleasant state, which facilitates performance (Bishop & Karageorghis, 2007).

Data from the present research programme indicate that the intensity of the emotional response appears closely related to the intensity of the stimulus, as borne out in quantitative affective data obtained in Chapter 4 and Chapter 5; this is also corroborated by participants' selection in Chapter 3 of higher music intensities for music tracks which they purportedly used in order to psych-up. Other research has suggested that increases in loudness are perceived by non-musicians most rapidly as alterations in emotional content (Schubert, 2004). The present data indicate that increases in arousal can be easily attained via manipulation of the intensity of any auditory stimulus, including non-musical stimuli (e.g., white noise). However, music listening is clearly a more ecologically valid and aesthetically pleasing strategy: Not only is it already used an emotion regulation strategy by young people (Saarikallio & Erkkilä, 2007; R. E. Thayer et al., 1994), but music also elicited significantly higher pleasantness ratings than did white noise conditions in Chapter 4 of the present thesis; and the variety of musical genres available means that stimulus habituation can be all-but eliminated.

7.3.2 *Valence and Intensity in Emotional Responses to Music*

Participants in Chapter 3 of the present research programme consistently selected music which they subsequently classified as eliciting feelings of high arousal and high pleasantness. Affective data from Chapter 4 showed that nine adjectives were typically used to describe states accompanied by arousal and pleasantness scores which collectively delimited the upper-right (positively valenced, aroused) quadrant of the circumplex model: *Aroused*, *astonished*, *content*, *delighted*, *excited*, *happy*, *glad*, *pleased*, and *satisfied*; two of these would have been classified as both highly pleasant and highly arousing (i.e., scores ≥ 7): *Delighted* and *excited*. Five of the pilot tracks in Chapter 6 were sited in the same quadrant: *Can't Get Enough*, *Insomnia*, *Jump Around*, *Love Don't Let Me Go*, and *Pump It*; only the selected track (*Pump It*) attained classification as *highly arousing* and *highly* *pleasant* according to the criteria used in this thesis. Despite the fact that cultural and technological developments in the UK have rendered music a more homogenous entity[2], with genre boundaries becoming more blurred accordingly, these five tracks can reasonably be described as of the *Dance* genre. Dancing is a very rewarding activity for young people in the UK, typically being associated with social contexts that are both positive and arousing, such as weddings, parties, and nightclubbing. Therefore, dance music may be used to elicit feelings of *excitement* and *delight*, which may in turn instigate a performance-facilitating approach response in young tennis players, incorporating enhanced affect and cognition (Ashby et al., 1999). However, Hanin (1997) noted that emotions such as *excited* and *overjoyed* (arguably a state of delight) were dysfunctional for athletic performance; this may be related to a shift in the athlete's attentional focus as a result of experiencing such emotions.

Some dimensional models of affect necessitate the presence of positive affect, negative affect, or both (Watson et al., 1988). However, inspection of Figure 4.5 shows that the majority of the adjectives which participants selected to describe their affective state were somewhat polarised according to valence; few of the descriptors were located around the middle scores (4-6) of the valence dimension. Thus, the coexistence of positive and negative affect seems highly unlikely; participants in the present research programme could readily identify the presence of one or the other, not both. For example, adjectives closely associated with low valence Affect Grid (Russell, Weiss et al., 1989) scores in Chapter 4 as a result of listening to auditory stimuli were *alarmed*, *angry*, *annoyed*, *depressed*, *distressed*, *frustrated*,

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[2] In July 2005, 56% of all UK households possessed an internet connection, half of which were broadband; 41% of those users listened to or downloaded music online (National Statistics Online, 2006). This increasing availability has devalued music, quite literally, and enabled "the little guy" to represent himself online (e.g., at http://www.newmusictalent.com).

and *tense*. However, no direct evidence was obtained to suggest that these states were detrimental to CRT performance. In fact, all-but-one of these descriptors (*depressed*) were associated with moderately high arousal, which appeared to be a good predictor of performance and performance-related measures throughout the present research programme. Further examination of the effects of musically-induced high arousal negative states on performance is warranted; such stimuli could activate Gray's (1994) Behavioural Inhibition System (BIS), or alternatively Panksepp's (1998) RAGE system – each of which would yield considerably different motor behaviour, with correspondingly different implications for sporting performance.

Emotional valence (the idea that emotions can be classified as positive or negative, Charland, 2005), and *affective valence* (the idea that emotional feelings can be classified as positive or negative, Charland, 2005) are pivotal to our everyday functioning, as they largely determine our behaviour in relation to the eliciting stimulus – whether it be approach or avoidance. Moreover, positive emotional states have typically been associated with improved cognitive functioning (Isen, 1987), and this appears to be mediated by increased activity of dopaminergic pathways (Ashby et al., 1999); dopaminergic neurons strongly innervate basal ganglia. It is proposed herein that the researcher-selected music heard in the present research programme was appraised in both a transactional self-referenced way (cf. Lazarus, 1991), due to the iconic representation of a highly aroused state, and in terms of their aesthetic qualities, such as melodic and harmonic aspects.

The arousal dimension of the circumplex model appears to possess far greater predictive value than does the valence dimension when considering subsequent reactive performance (cf. Larsen & Diener, 1992; J. F. Thayer & Faith, 2001), such as that used as an outcome variable in the present research programme. This is consistent with EEG evidence that the overall arousal state of the brain affects its information processing capacities

(Winterer et al., 1999). However, transient and enduring effects of listening to music should be differentiated, maybe in light of emotion-mood distinctions (e.g., Beedie et al., 2005). Evidence throughout the present research programme indicated that the intensity of the emotional response varied across time. In Chapter 5, the greatest extent of activations in emotion-processing areas (subcallosal cortex, posterior cingulate) was witnessed in the CRT task block, which began only after 90 s of the listening block, supporting Koelsch et al.'s (2006) observation that the most elevated neurophysiological response to pleasant music occurred in the second of two 30 s blocks. Chapter 5 data are bolstered by the ability of the emotional response to influence CRT performance after an equivalent duration (Chapter 4), and evidence of increased compound motor action potentials after, not during, a period of music listening (Chapter 6).

By reference to the model in Figure 3.2, it seems that the *listening-performance onset delay* is a crucial consideration for emotion management with music. The emotional response to music unfolds over time to reach a peak over a period that is greater than 30 s (Koelsch et al., 2006). However, this maximum is likely to wane rapidly, or we would otherwise experience prolonged and possibly inappropriate excitement, for example, in response to a favourite music track played at a loud intensity and a fast tempo. Nonetheless, improved mood was consistently noted as a consequence of listening to self-selected music in Chapter 3. Given the established link between mood and performance (Lane & Terry, 2000; Terry, 2004; Totterdell & Leach, 2001), the use of music at regular intervals during both training and competition to maintain positive affect and/or arousal at facilitative levels is merited.

7.3.3 An *Emotion-Motivation Systems Perspective*

Continually present throughout the later chapters of this thesis was research detailing the Mozart effect, a term first coined by Rauscher et al. (1993) to describe the improvements in spatiotemporal performance witnessed as an apparent result of listening to Mozart's sonata for two pianos in D Major (K.448). Subsequent research has been mixed in its support for the Mozart effect (Ho, Mason, & Spence, 2007; Rauscher & Shaw, 1998; Rideout et al., 1998; Rideout & Laubach, 1996; Schellenberg et al., 2007), but a judicious hypothesis for the observed performance improvements are changes in arousal and mood (Thompson et al., 2001). Similar changes were witnessed in the present programme of research in response to music exhibiting fast tempi, which may be the moderating factor in the Mozart effect; for example, Thompson et al. (2001) examined participants' performance on a task similar to that used in Rauscher et al.'s original study after listening to both the Mozart sonata and a slower piece by Albinoni, the mood of which was unsurprisingly classified as sad. Music tempo has been shown to affect valence judgements not only throughout the present thesis, but also in past research (Khalfa et al., 2005; Schubert, 2004; Webster & Weir, 2005).

The valence hypothesis (Hellige, 1993) posits that the left hemisphere is dominant in the expression of positive emotions, and the right hemispheric activation in the expression of negative emotions. This notion has since received support in music research: Schmidt and Trainor (2001) showed that positively valenced musically induced emotions (i.e., *joy* and *happy*) elicited greater left hemisphere activation, and negatively valenced emotions (i.e., *fear* and *sad*) elicited greater right hemisphere activation. However, intensity of emotion (cf. Frijda et al., 1992) determined overall frontal activation, which increased with the degree of survival-orientation of the associated action tendency (i.e., fear, the most intense of the four emotions, elicited the greatest amount of activity); this fits with Thayer and Faith's (2001) contention that arousal reflects the resource investment in the action tendency. The degree of frontal activation also appears to be a good correlate of reaction time performance in which approach responses are required (Winterer et al., 1999); and subjective arousal in Chapter 4 of this thesis was also negatively correlated with performance on a CRT task that necessitated approach responses.

Gray (1994) promoted his personality theory, which is based on the three basic emotion systems he deemed to exist in the human brain (see Section 4.2 and Figure 4.1 for elaboration). In the first of these, the behavioural approach (BAS) system, signals of reward induce an emotional state that activates dopaminergic pathways, which facilitates a positive affective state (cf. Ashby et al., 1999) and approach behaviour; an idea which has since been taken up by Panksepp (1998) in his SEEKING system. Chapters 5 and 6 of this research programme collectively yielded data to suggest that fast, loud, and subjectively arousing music can yield similar responses. The following section describes a model for those responses, grounded in present data.

7.4 A Simple Mechanistic Model of the Effects of Music Listening

Figure 7.1 depicts a simplified mechanistic representation of the proposed pathways leading to emotional-motivational consequences of playing music at a fast tempo (≥ 150 bpm) and at a high intensity (≥ 75 dBA), when contrasted with music played at slow tempo (≤ 99 bpm) at a moderate intensity (≤ 55 dBA). This model converges findings from the present thesis, utilizing existing knowledge of auditory perception mechanisms (e.g., Bear et al., 2007) and emotional responses to music (e.g., Menon & Levitin, 2005). It is mechanistic to the extent that it draws on the neurophysiological and electrophysiological data obtained this thesis, which corroborated affective and behavioural data. Relationships between functional nuclei of the brain are highly reciprocal and complex, and the model presented here cannot therefore represent a comprehensive explanation of those relationships; it is intended only as a descriptive synthesis of the key findings from Chapters 4-6.

The music stimulus is labelled as *biologically irrelevant*, as it has no survival value (see Panksepp, 1998); however, it can quickly become a conditioned stimulus to activation of ordinarily biologically-driven mechanisms if it has been previously paired with an emotive

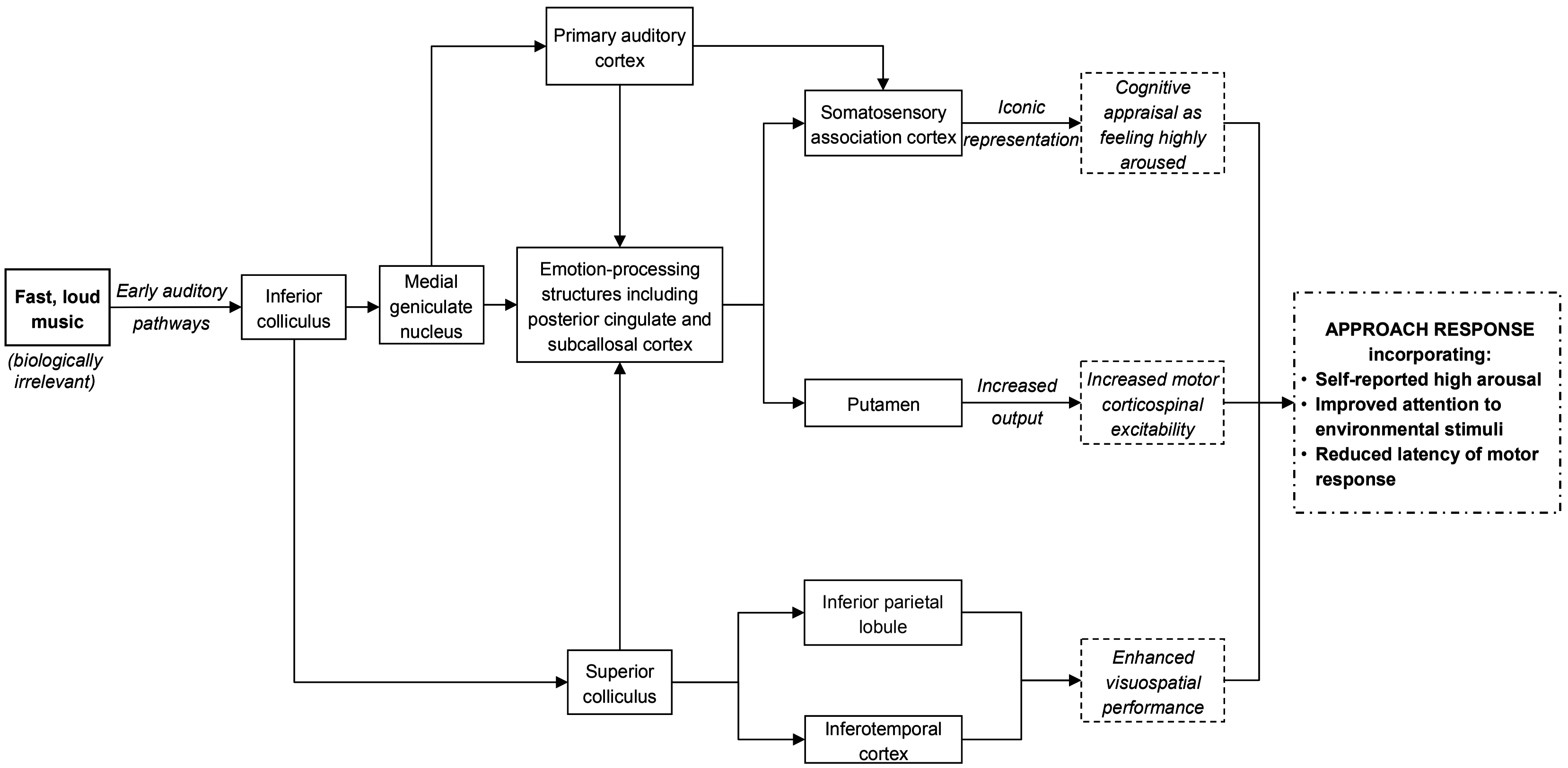

Figure 7.1. A simplified mechanistic model of the pathways leading to emotional-motivational consequences of listening to fast, loud music.

event, by way of Scherer and Zentner's (2001) *memory route*. However, the activations illustrated in the model occur in response to an *iconic* property (Sloboda & Juslin, 2001) of the stimulus: Fast loud music – independently of any other sources of emotion within the music – is considered here to be *iconically representative* of a highly aroused state. Therefore, it is proposed that listening to such music prompts a similar, albeit weaker, neurophysiological response to that encountered in a biologically-driven high-arousal state. Affective data reported in Chapter 4 show that fast loud music was perceived as significantly more arousing than music played at a slow tempo, at both loud and moderate intensities. Although both arousal and valence dimensions of emotional responses to music can be differentiated by autonomic system responses (Nyklícek et al., 1997), which are intrinsically primal in nature, there must be some degree of conscious representation of the bodily correlates of these affective dimensions so that the listener can describe the affective experience of what it is to be in an aroused state. Hence, somatosensory association cortex was included in the model, as a means by which the listener could integrate multiple sources of information, perhaps from *somatic markers* of emotion (Damasio, 1994), to yield both Affect Grid (Russell, Weiss et al., 1989) ratings and the accompanying descriptors.

Fast tempo and loud intensity collectively elicited significant activations in inferior temporal gyrus, subcallosal gyrus, inferior parietal lobule, and putamen, albeit at the fixed effects level of analysis. These activations were witnessed at the regions-of-interest (ROI) analysis level for stimuli perceived as highly arousing, when contrasted with low-arousing stimuli. Therefore, these structures were incorporated into the model, together with posterior cingulate – which was also activated significantly in ROI analyses in response to arousing stimuli. Although no significant activations were witnessed in the inferior/superior colliculi, or the medial geniculate nucleus (MGN), these structures were considered necessary inclusions in order to construct a coherent model.

It was speculated in Chapter 6 that the increased putamen activation observed in Chapter 5 should in turn implicate some greater degree of overall activation of the motor system – evidenced by increased corticospinal excitability. This assertion was upheld to a degree, and increased corticospinal excitability is therefore included in the model. Thus, the final output, as specified here is an appetitive *approach response*, which bears comparison to Gray's (1994) Behavioural Approach System (BAS) and Panksepp's (1998) SEEKING system. This response is typified by forward locomotion, heightened general arousal, and other behaviours related to exploration such as increased visual search. It should be noted at this point that the utility of such a response is greatest when considering reactive, open skills in sport; listening to fast, loud music prior to execution of a closed skill (e.g., the tennis serve) may be an inappropriate strategy.

7.5 Recommendations for Future Music Research in Sport

Investigation of the ability of music to moderate perceived exertion (Borg, 1962) during physical activity is commonplace (e.g., Atkinson et al., 2004; Bacon & Hookway, 2003; Boutcher & Trenske, 1990; Potteiger et al., 2000); and the analgesic effects of music are becoming increasingly researched, also (MacDonald et al., 2003; Mitchell, MacDonald, Knussen, & Serpell, 2007; Roy, Rainville, & Peretz, 2007). The ability to successfully manage perception of pain is pertinent to both sport and exercise contexts, and the increasing availability of neuroimaging technologies such as fMRI will enable researchers to investigate the mechanisms through which self-selected music can distract from painful stimuli. However, there is currently a limitation to this approach: Exercising in an MRI scanner is not particularly viable, as artefacts due to circulatory changes and participant movement are produced; further advances in image pre-processing may be able to circumvent this.

Tormos et al. (1997) found that happy imagery facilitated motor potentials evoked by right hemisphere stimulation using transcranial magnetic stimulation, while sad images facilitated left side stimulation; results of a follow-up study suggested that the changes were cortical in origin. Music is a potent conditioning medium (Eifert et al., 1988), and listening to familiar tracks is sufficiently potent to activate similar neural structures to those used in auditory perception (Halpern & Zatorre, 1999; Kraemer et al., 2005). Participants in Chapter 3 of the present research programme frequently reported imagery as a consequence of listening to self-selected emotive music – in both visual and auditory modalities. Therefore, the use of combined TMS/fMRI to explore the ability of music to act as a conditioned stimulus to elicit strongly emotive visual imagery, and the consequent effects on corticospinal excitability represents a challenging but potentially productive line of investigation.

Mean Affect Grid (Russell, Weiss et al., 1989) ratings in Study 3 were considerably different from those in Study 2; this resulted in different categorisation of the various auditory stimuli, which serves to reinforce the idea that it was the emotional response being measured, but evokes the question of why two samples from the same population rated the musical conditions so differently. Recent evidence suggests that environment might have played a part. For example, Baumgartner and his colleagues (Baumgartner, Esslen et al., 2006; Baumgartner, Lutz et al., 2006; Baumgartner et al., 2007) have demonstrated that emotive visual stimuli and emotive music interact to produce a combined emotional responses that is considerably greater than that to emotive music alone. Therefore, future research should consider the environment, especially when considering action tendencies (Frijda, 1987) as a result of music listening; the additive effect of an emotive visual stimulus with emotive music may promote even more adaptive responses than were witnessed in this thesis. Music is a powerful conditioning tool (Blair & Shimp, 1992; Eifert et al., 1988; Janiszewski & Warlop, 1993), and therefore may easily be conditioned – perhaps via creation of performance highlight videos (Templin & Vernacchia, 1995) – to elicit such a powerful emotional response when presented in isolation; this is arguably a more straightforward strategy than viewing a video prior to performance.

7.6 Practical Implications for Music Use in Sport

The present results have implications for emotion and arousal management prior to competition. The extrinsic sources of emotion contributing to an athlete's response to a music selection are typically very individual, and this alone has rendered the classification of music difficult, which is something Karageorghis and his colleagues have twice sought to ameliorate (Karageorghis, Priest et al., 2006; Karageorghis et al., 1999). However, in developing a model of tennis players' music use to manipulate emotional state (Figure 3.2), an extension of Karageorghis et al.'s (1999) earlier work is provided.

The model embraces the notion of idiosyncratic music use, offering a *route map* rather than an instruction, for practitioners and athlete alike to maximise their chances of selecting music appropriately. Applications of Hanin's (1995; 1997) IZOF model continue to prevail in emotion research in sport, across a range of team and individual sports (Cohen, Tenenbaum, & English, 2006; Edmonds et al., 2006; Hagtvet & Hanin, 2007). IZOF-based models can be used to predict an athlete's functional emotional profile, arguably more successfully than more traditional nomothetic measures (e.g., CSAI-2; Martens et al., 1990); Cerin's (2003) research strongly supports the notion of using fundamental emotions to predict performance. A question which naturally follows from IZOF research poses is, "Now that we know what [athlete]'s optimal emotional profile is, how do we go about creating it?" Given the capacity of carefully-selected music to rapidly and effortlessly elicit profound autonomic (Rickard, 2004), affective (Gabrielsson, 2001), neurophysiological (Blood & Zatorre, 2001) and behavioural (Bishop & Karageorghis, 2007) responses, in combination with the flexibility offered by contemporary technological developments (e.g., the iPod), now is an ideal time for athletes to experiment with tracks from their *pool of emotive music*, to bring about a performance-facilitating profile, using the present model as a guide.

In keeping with the applied focus of this thesis, the following guidelines were developed, for athletes who wish to optimise their pre-performance music use.

1. Be sensitive to the five *determinants of emotive music* detailed in the first stage of the model from Chapter 3; these predominantly extrinsic sources of emotion will help you to establish a sliding scale of your personal emotional responses to music, from *relatively minor* to *elicits chills* (Goldstein, 1980).
2. Note down what you could conceivably describe as your typical responses to 20 of these tracks, which now constitute a finite *pool of emotive music*. Create a playlist on your MP3 player of these tracks, entitled *pre-performance music*.
3. When seeking to moderate your emotional state, consider your *present emotional state* and *desired emotional state*, in terms of both valence and arousal: Does your affective state need to become more or less positive; and does your state of arousal need to be increased or decreased? It may be the case that maintenance of one or both of these is required.
4. Stay attuned to your environment. Combinations of emotive music with equally emotive visual stimuli may lead to an enhanced response (cf. Baumgartner, Lutz et al., 2006) – which may or may not be desirable.
5. Bearing points 3 and 4 in mind, select a track from the pool whose *extra-musical associations* are likely to engender the desired emotional state. The impact of the track may be moderated further by the amount of exposure you've had to the track recently, the acoustical qualities such as tempo (faster tempi will likely elicit happier responses), and inspirational and catchy lyrics, which may enable you to sustain the emotional response as you sing to yourself (Halpern & Zatorre, 1999).

6. Once a track has been selected, a decision needs to be made about the timing of the desired peak for the emotional response. Evidence suggest that 90 s of listening to music can elicit neural changes that continue to rise after cessation of the music (Bishop et al., 2007); and the response during listening is greater after 30 s of listening (Koelsch et al., 2006).
7. The intensity of the emotional response is affected by the fidelity of the music delivery system, which also may affect the impact of background noise (cf. Baumgart et al., 1998). Higher quality systems and in-the-ear delivery are likely to maximise the intensity.
8. If some type of reactive performance will follow music listening, then higher intensity (volume) and faster tempi will likely improve performance. However, caution should be exercised when listening at loud volumes for prolonged periods (The Health and Safety Executive, 2005). Use the *time scaling* features of your MP3 player to increase or decrease the tempo.
9. Note your responses, for future reference, together with all relevant performance outcomes.

7.7 Summary

This thesis encompassed the triangulation of a diverse combination of methods to elucidate tennis players' emotional responses resulting from listening to music. A decade on from Karageorghis and Terry's (1997) review of the psychophysical effects of music in sport and exercise, the present programme of research answers many of their calls for a number of criteria to be addressed. First, the music used in Chapters 4 and 5 was researcher-selected and its properties were detailed thoroughly; this allowed the reader to judge the reliability and validity of the present findings for him or herself. Second, music intensity was reported throughout the programme, as was the mode of delivery (e.g., earphones, headphones, or loudspeakers); both of these features have important implications for the ecological validity of music research, and have been incorporated into a subsequent model of music use for emotion modulation (Bishop et al., in press).

Throughout this thesis, the temporality of emotional responses to music has been highlighted (Bishop et al., in press; Koelsch et al., 2006); this has enabled the researcher to develop a clear position on the potential ergogenic benefits to be derived from the emotional response to music. Present data only allow the identification of an approximately 30 s period from cessation of music listening, in which performance-facilitating emotional profiles may still remain; although this may be longer in actuality. Finally, the decision to focus solely on competitive tennis players reflects the author's acknowledgment that a host of sociocultural factors impact on music preferences (North & Hargreaves, 2007; North et al., 2004). The selection of *Deepest Blue* for use in Chapters 4 and 5 was guided by an attempt to optimise the emotional response to the track, based on prior musicological research findings (e.g., North & Hargreaves, 1995); and the selection of the track in Chapter 6 was enabled by use of a pilot sample bearing similar demographic characteristics to those expected to constitute the main study sample. The findings of this thesis are thus arguably only generalisable to competitive tennis players; the wider implications are for the reader to judge.

The principal contribution of this thesis to the extant literature is to show that music variables may be carefully selected and/or manipulated to educe performance-facilitating emotional responses to music in competitive tennis players. Many sources of emotion contribute to the listener's *pool of emotive music*; but the strategy of listening to personally emotive music with a fast tempo, played at a loud intensity is likely to heighten subjective arousal, positive affect, and choice reaction time performance. A subcortically-mediated emotional response diffusely activates areas of the brain implicated in motor control, decision making, and integrative sensorimotor and visuomotor processing – ultimately promoting *approach* action tendencies (Frijda, 1987). This behavioural readiness is a defining feature of appetitive emotion-based motivation systems (e.g., Gray, 1994; Panksepp, 1998), and provides a route to success in not only sport, but also life.

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APPENDICES

APPENDIX A: Publications Emanating from the Present Research Programme

Peer-Reviewed Journal Articles – Submitted and Projected

Bishop, D. T., & Karageorghis, C. I. (2007). *The affective and behavioural consequences of manipulating tennis players' emotional state via music listening*. Unpublished manuscript.

Bishop, D. T., Karageorghis, C. I., & Loizou, G. (in press). A grounded theory of young tennis players' use of music to manipulate emotional state. *Journal of Sport & Exercise Psychology*.

Bishop, D. T., Ross, E. Z., & Karageorghis, C. I. (2007). *Corticospinal excitability and motor neuron recruitment as a function of pre-performance music listening*. Unpublished manuscript.

Bishop, D. T., Wright, M. J., & Karageorghis, C. I. (2007). *Neurophysiological indices of emotional responses to music listening and subsequent choice reaction time performance*. Unpublished manuscript.

Book Chapter to Be Submitted

Bishop, D. T. (TBC). Using music to optimise emotions in sport. In J. R. Bale (Ed.), Sporting Sounds. London: Routledge.

Conference Abstracts

Bishop, D. T. (2006). *A grounded theory of young tennis players' use of music*. Paper presented at the BASES Annual Conference 2006, University of Wolverhampton, Wolverhampton, UK.

Bishop, D. T., & Forzoni, R. (2006). *The use of music video in sport psych interventions: Empirical and anecdotal considerations.* Paper presented at the BASES Annual Conference 2006, University of Wolverhampton, Wolverhampton, UK.

APPENDIX A (continued)

Bishop, D. T., & Wright, M. J. (2007, April). Neurophysiological correlates of tennis players' emotional responses to pre-performance music. Paper presented at the Centre for Cognition and Neuroimaging Conference, Brunel University, West London, UK.

Other publications

Bishop, D. T. (2005, May). The Sound of Music. *220 Triathlon*, 56-57.

APPENDIX B: Chapter 3 Initial Music Questionaire

Thank you for giving up a few minutes to complete this questionnaire

Brunel
UNIVERSITY
WEST LONDON

Please note: All information you provide will be treated as **strictly anonymous**; your name and contact number are required only so that I may contact you at a later stage of my research, with your permission.

First Name: ___________________________ **Last Name**: ___________________________ **Age**: ______ years ______ months

Gender: Male / female (please circle one) **Contact tel no.**: ________________________________ **Date**: _____ / _____ / _____

Please note your tennis ratings/rankings, where applicable:

LTA ☐ ITF ☐ ETA ☐ WTA ☐ ATP ☐

1) Which type(s) of music do you like listening to? E.g., rap, R&B, garage, etc.

____

____

2) Name any artists you especially like listening to:

____

____

3) Do you ever listen to music as part of your match preparation? Yes / No

a) If yes, please try to name the tracks and/or artists you like/use the most, together with a brief explanation of why you like them, or use them:

____

____

____

____

4) In which situations do you purposely listen to music? Please rank the situations below according to how often you listen in the situation (*1 = most often*). If you never listen to music in one of the situations listed, then leave its box blank. Add your own situations if you would like to.

At home – bedroom ☐ At home – other ☐ Tennis Centre ☐ Travelling to Centre ☐

Doing a workout ☐ Travelling to competitions ☐ ____________________ ☐ ____________________ ☐

5) For how many years have you been playing competitive tennis? _________ years

6) What is your 'tennis goal'? In other words, what would you like to achieve by being at the centre? Perhaps you have you heart set on becoming a coach, or a full-time professional; perhaps you want to go to university and play for the university team…please continue on the back if you have more to say!

____

____

7) When do you hope to achieve it by, very approximately? Please give a month and year. MM / YY

Thank you for your help! **Dan Bishop (07939 526536)**

APPENDIX C: Chapter 3 Interview Guide

Name: ___________________________

Track & Artist	**Psychological Quality**	**Volume (dB)**	**Tempo (bpm)**

Physical Properties			
Do you listen to the lyrics of the track? Do you know them off by heart?	Vocalist – male / female	Any particular segments?	Are there any artists whose music is very similar to this one? Why not pick theirs?

Associative qualities				
Why did you select this track for this purpose?	Does it make you think of anything in particular? If so, what??	Do you know the video for this track?	People, places, events…	What does this artist represent to you?

APPENDIX C (continued)

Name: ___________________________

Cultural Norms

How do you think that this music is perceived by your peer group? Is it cool?	What about the artist's image? Is that cool?	What do your friends listen to?	

Imagery

What kind of thoughts, feelings, and images does this track conjure up?	See yourself playing well in a match. Describe yourself for me, please.	How do you imagine yourself when you are listening to this track?	

Listening Habits

How much time would you say you spend listening to music each day or week? How often do you listen to this track?	Do you watch any music video channels? How often?	Where are your top three places for listening to music? How do you listen to music most? E.g., iPod, car stereo, etc.	How often does music form the main activity? How often does it accompany something else you are doing?

APPENDIX D: Participant Music Diary

About your day

___ /___ / 05

Jot down any music you heard
(doing this throughout the day will make life easier!)

How did you spend your time today? E.g., "*8.30 'til 13.00, I was preparing for my match at the Oxford 10K*"

Time	**Activity**	**Music – artists, tracks, genres, radio stations…**
______ 'til ______	, I was ____________________	____________________
______ 'til ______	, I was ____________________	____________________
______ 'til ______	, I was ____________________	____________________
______ 'til ______	, I was ____________________	____________________
______ 'til ______	, I was ____________________	____________________

Are you listening to music as you write this? What is it?

Please rate the music for liking 1 2 3 4 5 6 7 8 9 10 11
Please rate the music for arousal 1 2 3 4 5 6 7 8 9 10 11

Your use of music today...

Try to think of ONE memorable music listening episode today:

1) HOW were you listening to it? E.g., via iPod, car stereo… ______________
2) What was the VOLUME? Very quiet 1 2 3 4 5 6 7 Very loud
3) WHY did you choose to listen to this particular track/artist/type of music ?
____
____
____

4) How did you feel BEFORE hearing it?
____
____

5) What effect did the music have on your mood/behaviour, if any?
____
____
____

6) What do you associate with this music?
____
____

Evaluating your tennis performance today

What went well today? ______________________
____
____
____
____

What didn't go so well? ______________________
____
____
____
____

How did you feel, generally? ______________________
____
____

APPENDIX E: Chapter 3 Initial Questionnaire Responses

ID	LTA	Age	Gender	ITF	ETA	WTA	ATP	Genres	Artists	Music as Prep.
1	2.1	19.00	M				1470	Indie, light rock	Damien Rice, Coldplay, David Gray, Matchbox 20	Yes
2	2.1	23.00	M					Rap, R&B, Garage, Rock, Easy Listening, (A bit of everything)	Eminem, Black-eyed Peas, Maroon 5, Oasis, Bruce Springsteen	Yes
3	2.2	18.00	M	300				Dance, R&B, Rap	Angel City, United Nations, Eminem	Yes
4	2.2	20.25	M					R+B, Garage, Rock	Jay-Z, 5o Cent, Eminem, Matchbox 20, Goo Goo Dolls	No
5	2.2	18.50	M					R&B, Old School, Love songs (don't laugh!)	Britney! The Bangles, Jay-Z, 50 cent	Yes
6	3.1	17.50	M	700				Rap, Hi Hop, Techno	2pac and Nas	Yes
7	3.1	16.00	F	325				R&B, pop	Usher, Justin Timberlake, Joss Stone, Jenifer Lopez	Yes
8	3.1	16.50	F	800		0.75 pts		Pop, Hip Hop, R&B (most things)	Ashlee Simpson, Maroon 5, Usher	Yes
9	3.2	19.50	F					Most music	Haven't got favourites	No
10	3.2	15.50	F		2.4			R&B, punk rock, pop rock, dance	Blink 182	No
11	3.2	17.75	M					Rap, Hi Hop, Garage	2pac	No
12	4.1	16.25	F					Pop, rap, R&B	Justin Timberlake, Ashlee Simpson, Eminem	Yes
13	4.1	16.75	M					Garage, Rap, D & B	omarion, Dee (MCs in general)	Yes
14	4.1	17.75	F					Anything, no particular type	Usher, Green Day, Gwen Stefani, Justin Timberlake	Yes
15	4.2	18.75	M					Some rock, some pop, classical	Avril Lavigne, Alicia Keys, Scissor Sisters, Maroon 5, Franz Ferdinand, Queen, Beatles, Chopin, Beethoven Mozart	No
16	4.2	17.50	M					Rap, gangsta rap, west coast, east coast, mid-west, south coast, freestyle rap, rap battles etc.	Tupac, Biggie, Big C, Mobb Deep, Big Pun, Immortal technique, Outlaws, M.O.P., Krumb snatcha, cormeaga, capone, noreaga, ghostface killa, nas, Kool G rap, Big Syke	Yes
17	4.2	18.00	M	2.5				Rap	2 Pac	Yes
18	4.2	19.50	M					Hip Hop, R&B, Garage	Fat Joe	No
19	4.2	19.50	M					Hip Hop, RnB	Kanye West, 50, game, ganit	No
20	4.2	17.75	M					Rock / House	Blink 182, Sum 41, Green Day, Linkin' Park, Faithless	Yes
21	5.1	18.75	M					Hip Hop, R&B,	Fat Joe, Eminem, Dr Dre	No
22	5.1	17.50	M					Rock	Blink 182	No
23	5.1	20.50	F					Most types of music but especially rock, RnB hip hop, some alternative	Eminem, Nightwish, Linkin Park, yellowcard, nirvana, dixie chicks, Avril Lavigne, Evanescence, Alicia Keys	No
24	5.1	17.00	M					Garage, rap, R&B Hip hop	Kano, Usher, Nas, Jay Z, Eminem	Yes

APPENDIX E (continued)

ID	LTA	Age	Gender	ITF	ETA	WTA	ATP	Genres	Artists	Music as Prep.
25	5.1	14.33	F					R&B, Urban, Pop, Bit of Rap	Greenday, Natasha Bedingfield, Nelly, Usher, Ashlee Simpson, Maroon 5, Scissor Sisters	No
26	5.2	13.00	F					I listen to R&B music	Akon, Ice Cube, 50 Cent, LL Cool J, Usher Natasha Bedingfield	No
27	5.2	21.75	M					Electro-Techno-House; Classic; French and English songs	Hans Zimmer (OST); French singers like Goldman, Renaud, Brassens Scratch Massive; Mozart; Handel	Yes
28	5.2	15.33	F					R&B, Urban, Pop	50 Cent, Blue, Eminem, Ashlee Simpson, R Kelly, Nelly, Justin Timberlake	No
29	5.2	16.75	M					Hip Hop / Garage	Jay-Z, Kano, Nas	Yes
30	6.1	16.00	M					Rap, R&B	2Pac, Usher, Destiny's Child, B2K, Akon	Yes
31	6.1	12.75	F		321			R&B, pop	Joss Stone, Usher, Jennifer Lopez, R Kelly	Yes
32	6.1	18.00	M					All sorts, rock, etc.	Blink 182, Sum 41	Yes
33	6.2	16.50	M					Rap, RnB, Garage, House	Pretty much everyone	Yes
34	6.2	17.50	M					Rap, RNB, Garage Drum + Bass	Kano, 2Pac, Biggie	Yes
35	6.2	18.50	F					Indie, Garage	The Killers, Green Day, Avril Lavigne	No
36	7.1	15.50	F					R&B, Rap	50 Cent, LL Cool J, Usher	No
37	7.1	17.50	M					Hip Hop, Rock , Acoustic	50 cent, Badly Drawn Boy, Red Hot Chilli Peppers	No
38	7.2	12.00	F					Rock, pop, a bit of rap	Maroon 5, AC/DC, Guns n' Roses, Natashe Bedingfield	No
39	8.1	16.50	M					Rap, R&B and Garage	Snoop Dogg, Kanye West, Ciara	Yes
40	8.1	15.60	M					R&B	Usher, R. Kelly	Yes
41	8.2	16.00	M					Hip Hop	Ludacris, Marques Housten, Jagged Edge, Eminem, Tupac, Dr Dre, Usher	Yes
42	9.1	14.75	M					All	All	Yes
43	9.2	16.50	M					Hip Hop, Garage, Reggae, Dancehall	Talib, Kwely, Taz	No
44		17.25	F					R&B	Akon, Usher, Celine Dion	No
45		18.50	M	200				Rap, R&B, Pop, Garage	Jay-Z, Game, 50 cent, G-Unit, Nas	Yes
46		22.00	F			FFT:15		Pop, R&B, house, hip hop, rap	U2, Kyo, Cormeialla	Yes
47		18.25	M	103				House, dance, rap, 80s		Yes

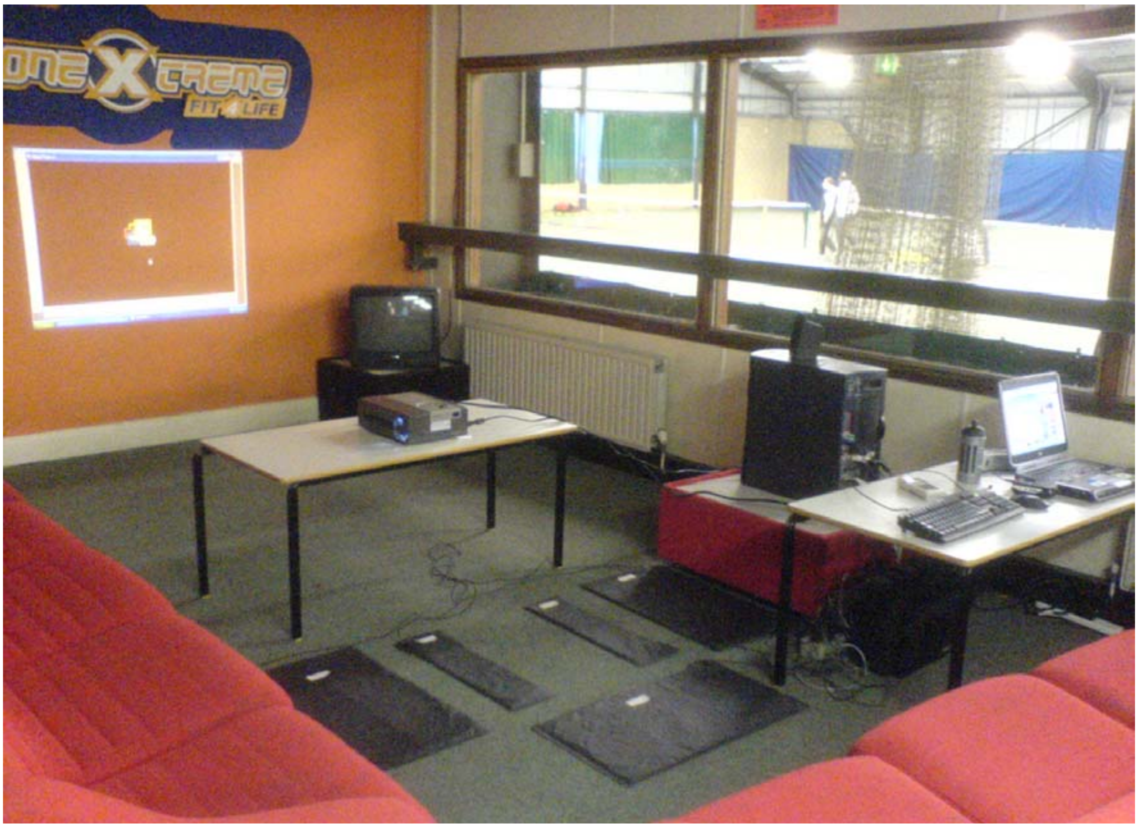
APPENDIX E (continued)

ID	Tracks and Artists and explanations	Bedroom	At home -other	Tennis Centre	Travelling to Centre	Doing a workout	Travelling to comp.	Other	Years playing tennis
1	Elton John (Original Sin) John Secada (Just Another Day). They are sad songs and remind me of when I played bad and how I vowed to work harder and keep on improving so I wouldn't feel those bad feelings again. Also it helps remind me of all the effort put into me and how I have to repay them.	1		1	1	1	1		**8**
2	Rocky Soundtrack - Because it is great motivation (reminds me of the film) Anything loud and fast - gets me pumped	3			2		2		**13**
3	Angel City - Gets me feeling in a positive mood. Eminem - Gets me going and feeling good before my match				1	1	1		**7**
4				3	1	2	1	1 - in my car	**9**
5	Rocky soundtrack	1		1	1	1	1		**8**
6	Eye of the Tiger: It gets me pumped	1	4	3		5	2		**5**
7	Rocky - motivating, Usher - upbeat, Jenifer Lopez - lively, Joss Stone - inspiring	4		2	3	5	1		**6**
8	Ashlee Simpson cause it gets me pumped up (la la)	4	3	3	2	1	1		**5.5**
9		3	6	7	2	4	5	1 - when driving	**7**
10					1	1		1 - falling asleep	**6**
11		1	3	2	4	5			**10**
12	Ashlee Simpson, Rocky because it pumps me up	1	2	6	5	4	3		**5**
13	Joe Budden - gets me hyped up/angry - in the zone	1	1	1	1	1			**5**
14	Eye of the Tiger	3	4	5	2	6	1		**6**
15		2	5		4	3	1		**8**
16	Shock one Pt 2 (Mobb Deep), Tradun War Stories (Tupac), 2 minute freestyle (Big C), Harlem Streets (Immortal technique), Thug Muzik (Mobb Deep), Straight Thuggin' (C-Bo), Fall Back (Big C), Wolves (Krumb Snatcha feat. M.O.P.), Money Rolls (Big Noyd), Rize (Big Syke), When we ride (Tupac feat Kastro + mussolini)	1	3			4		Headphones - 2 On computer - 5	**3**
17	I like to listen to 2pac before my match. It gives me motivation to win. 2pac is the greatest Rap and Hip-hop artist of all times and his lyrics are meaningful and inspiring	2	2	2	1	1	1		**12**
18		1	2	5	3	6	4		**3**
19		1	1	5	1	1	1		**6**
20	Blink, Sum 41 - FA. Quick tempo, gets me more highly motivated to work	1	3	6	5	4	2		**9**
21		1	5		2	3	4		**3**
22		1							**6**
23		1	3			2	4	1 - car	
24	Usher and Kano, I like Usher's melodies on his songs and I like Kano's lyrics	1	1	4	1	3	1		**6**

APPENDIX E (continued)

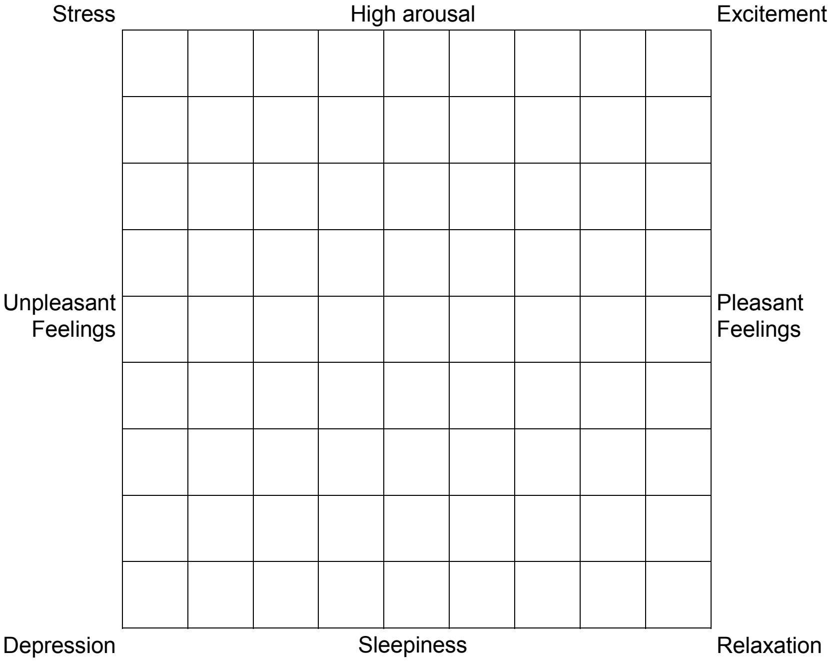
ID	Tracks and Artists and explanations	Bedroom	At home -other	Tennis Centre	Travelling to Centre	Doing a workout	Travelling to comp.	Other	Years playing tennis
25		3			2	4	1		**5**
26		1	2	5	3	1	4		**3**
27	I listen to Electro, when I'm training in the gym center, it gives me rhythm and motivation. Sometimes when I am playing I sing in my head the song I like at the moment to give up stress	1		3			2		**4**
28		1					2	3 - on holiday	**3**
29	Mobb Deep, Twista, W Tang clan…Because it is aggressive music and it pumps me up	1	1	1	1	1	1	1 - school	**7**
30	2Pac, Usher, Destiny's Child, B2K, Akon - cos it sykes me up	1	1	1	1	1	1		**7**
31	R Kelly - World's Greatest makes me confident for my match. Eminem Toy Soldiers gets me energised	2			2		3		**4**
32	Blink 182 - Wendy Clear - my favourite song and its loud	1	5	3	3	3	1		**3.5**
33	ATB - Til I come; Faithless - Insomnia, reason being theres a lot of beats and it gets pumped		1	1	1	1	1	1 - car	**4**
34		1		1	1	1	1		**7**
35		1					1		**4**
36		1	1	5	3	3	3		**4**
37		4	2	1	6	5	3		**5**
38		1	3	2	5	3	4		**2**
39	Kanye West - College Dropout, whole album; inspirational music	2	3	4	1	5	6		**2.5**
40	Burn, Yeah, I Believe I can Fly	5	4	1	5	4	1		**1.5**
41	Any music that's good at the time to try take my mind off the match	1	2	5	6	3	4		**3**
42	Red Hot Chilli Peppers takes the nerves away. Usher Burn superstition	5	4	4	1	3	1		**2 to 3**
43		1	1				1		**2**
44		4	2	1	3	5			**1.5**
45	I like to listent to certain songs cause they make me feel good and remind me of of good moments and times. Some of songs also get me "pumped"	3	4	6	1	2	5		**7**
46	I always listen to music but not special tracks or artists, it depends on the kind of music I am listening to	1	2	4	5	6	3		**10**
47	House or 80s, because relaxes me, keeps my mind happy	5	3	1	1	2	1		**x**

APPENDIX F: Chapter 4 Pilot Testing Setup



APPENDIX G: Affect Grid (Russell, Weiss et al., 1989)

Please place a cross in ONE square to rate how you feel RIGHT NOW



APPENDIX H: Affective Descriptors

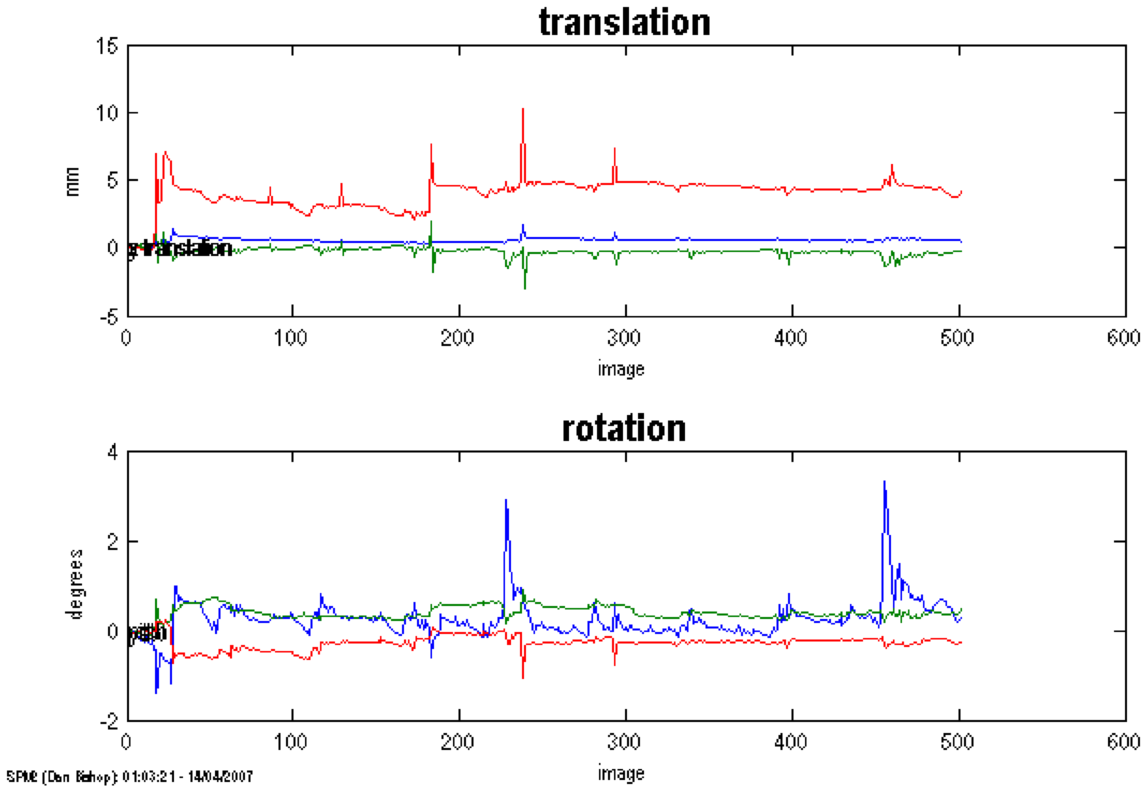
Please CIRCLE any words from the following list that describe how you feel RIGHT NOW. You may feel NONE of them; this is fine.

alarmed
afraid
angry
annoyed
aroused
astonished
at ease
bored
calm
content
delighted
depressed
distressed
droopy
excited
frustrated
glad
gloomy
happy
miserable
pleased
relaxed
sad
satisfied
serene
sleepy
tense
tired

APPENDIX I: Relaxation Script for Chapter 5

I would like you to close your eyes…you feel warm inside…your legs, arms, and head feel very heavy, and you sink into the bed…breathe in slowly and deeply through your nose for a count of three, and breathe out gently for count of four…as you do this, notice your belly button rising and falling in time with your breathing…continue breathing slowly and deeply…you feel calm…[10 s pause]…now open your eyes.

APPENDIX J: Screen Dump of the Rigid-Body Transformation Plots of Discarded Data.



APPENDIX K: Chapter 3 Participant Information Sheet

Participant Information Sheet

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Title of Research Project:	A Grounded Theory of Young Tennis Players' Use of Music
Principal Researcher:	Daniel T. Bishop, BSc (Hons), MSc. PhD research student School of Sport & Education Brunel University Uxbridge Middlesex UB8 3PH
Purpose of study:	To investigate the current use of music by young tennis players

Thank you for agreeing to take part in this study. By being a participant in this study, you can expect to:

- Complete a simple questionnaire
- Take part in an interview, which will be recorded
- Complete a page-a-day diary over a period of up to two weeks. You will receive up to three text messages per day, from the researcher, for this period; you will not be required to reply to any of them
- Possibly take part in a follow-up interview

All information that you provide will be treated as strictly confidential, and you are free to withdraw from the study at ay time, to absolutely no personal disadvantage.

If you have any questions, please ask. Thank you.

Dan Bishop

[redacted]

APPENDIX L: Chapter 4 Participant Information Sheet

Investigating the Effect of Music Listening on Choice Reaction Time

Participant Information Sheet

Thank you for agreeing to take part in this research study. Please note the following important information:

- Your involvement in my research study is completely voluntary
- You are entirely within your rights to withdraw from the study AT ANY TIME, to no personal disadvantage
- All information you provide will be treated as strictly confidential, unless you agree otherwise
- You will remain completely anonymous throughout

Below is a brief summary of what you can expect to do in this study:

1) Listen to music and other sounds
2) Record how you feel, on a sheet of paper
3) Perform a reaction time task

If you have any questions before, during, or after your participation, please ask me. Alternatively you can contact me any time afterwards, either via e-mail: daniel.bishop@brunel.ac.uk;

or on my mobile phone: [redacted]

Thank you for your assistance. I hope you will find this experience interesting and useful!

Dan Bishop

APPENDIX M: Chapter 5 Participant Information Sheet

Participant Information Sheet

Title of Study:	Investigating neural correlates of Choice Reaction Time Performance in Tennis Players
Principal Researcher:	Daniel T. Bishop, BSc (Hons), MSc. PhD researcher School of Sport & Education Brunel University Uxbridge Middlesex UB8 3PH

Thank you for agreeing to take part in this study. By being a participant in this study, you can expect to:

- Complete a simple questionnaire
- Lay in an MRI scanner for approximately 25 minutes (please see the attached Information Sheet), during which time you will
  - Listen to music via headphones, which is played at two different volumes and three different speeds, whilst laying in the scanner
  - Perform a Choice Reaction Time Task, in which you must respond to stimuli appearing on a screen, by pressing corresponding buttons on a handheld box

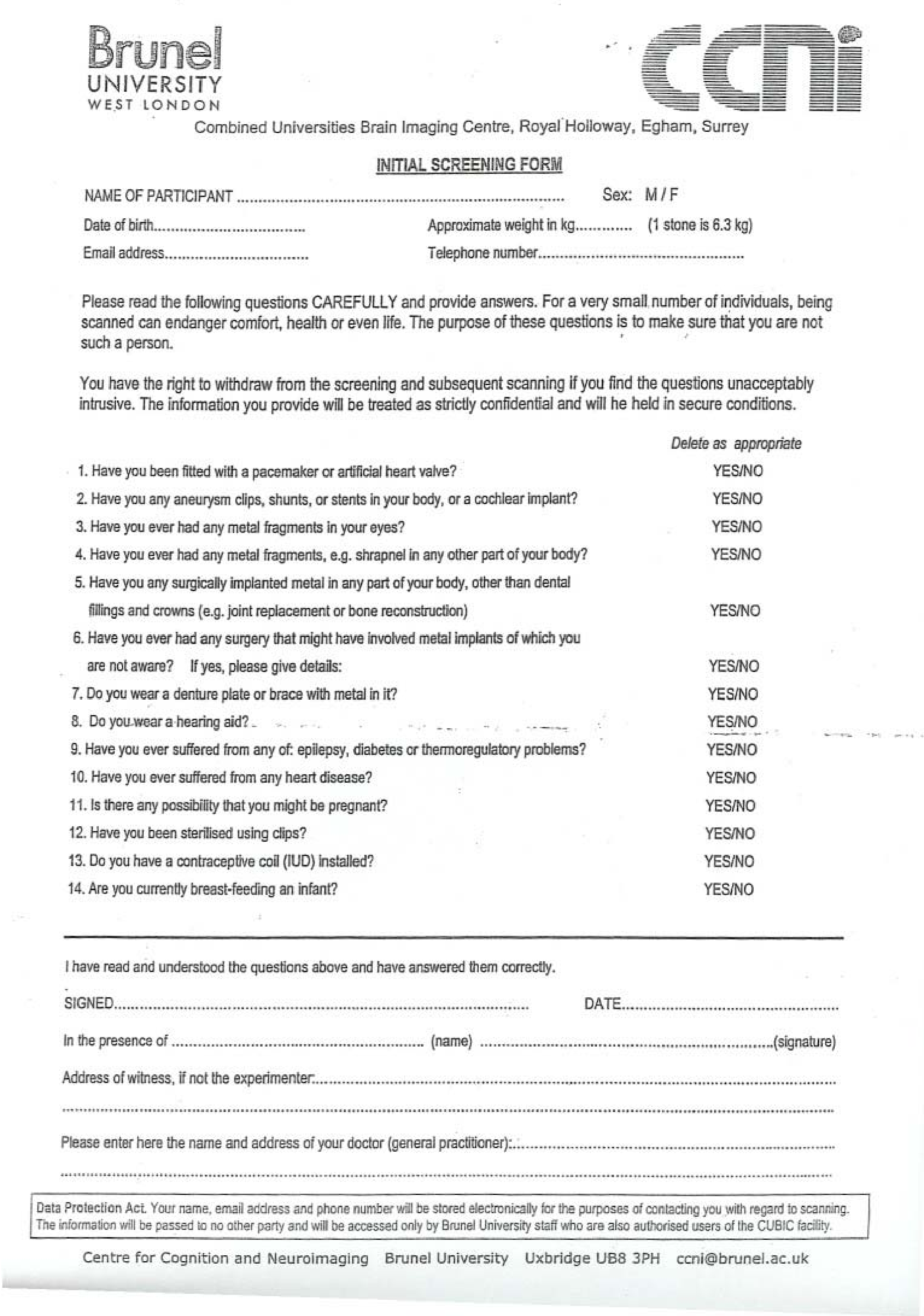
All information that you provide will be treated as strictly confidential, and you are free to withdraw from the study at any time, to absolutely no personal disadvantage.

If you have any questions, please ask. Thank you.

Dan Bishop

[redacted]

APPENDIX M (continued)



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Combined Universities Brain Imaging Centre, Royal Holloway, Egham, Surrey

INITIAL SCREENING FORM

NAME OF PARTICIPANT .... Sex: M / F

Date of birth.................................. Approximate weight in kg............ (1 stone is 6.3 kg)

Email address................................ Telephone number...

Please read the following questions CAREFULLY and provide answers. For a very small number of individuals, being scanned can endanger comfort, health or even life. The purpose of these questions is to make sure that you are not such a person.

You have the right to withdraw from the screening and subsequent scanning if you find the questions unacceptably intrusive. The information you provide will be treated as strictly confidential and will he held in secure conditions.

	Delete as appropriate
1. Have you been fitted with a pacemaker or artificial heart valve?	YES/NO
2. Have you any aneurysm clips, shunts, or stents in your body, or a cochlear implant?	YES/NO
3. Have you ever had any metal fragments in your eyes?	YES/NO
4. Have you ever had any metal fragments, e.g. shrapnel in any other part of your body?	YES/NO
5. Have you any surgically implanted metal in any part of your body, other than dental fillings and crowns (e.g. joint replacement or bone reconstruction)	YES/NO
6. Have you ever had any surgery that might have involved metal implants of which you are not aware? If yes, please give details:	YES/NO
7. Do you wear a denture plate or brace with metal in it?	YES/NO
8. Do you wear a hearing aid?	YES/NO
9. Have you ever suffered from any of: epilepsy, diabetes or thermoregulatory problems?	YES/NO
10. Have you ever suffered from any heart disease?	YES/NO
11. Is there any possibility that you might be pregnant?	YES/NO
12. Have you been sterilised using clips?	YES/NO
13. Do you have a contraceptive coil (IUD) installed?	YES/NO
14. Are you currently breast-feeding an infant?	YES/NO

I have read and understood the questions above and have answered them correctly.

SIGNED.. DATE..

In the presence of .... (name) ....(signature)

Address of witness, if not the experimenter:...

....

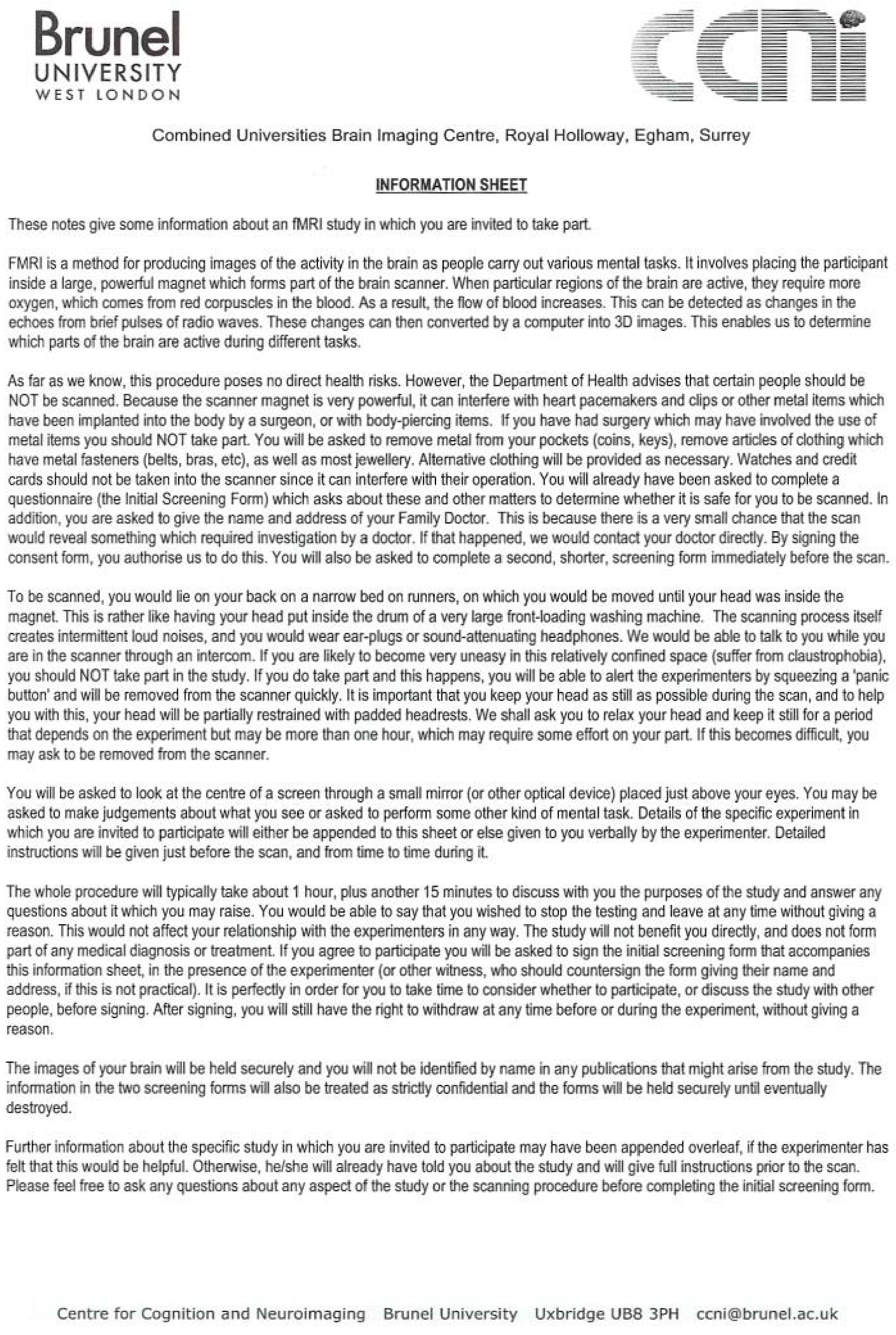
Please enter here the name and address of your doctor (general practitioner):...

....

Data Protection Act. Your name, email address and phone number will be stored electronically for the purposes of contacting you with regard to scanning. The information will be passed to no other party and will be accessed only by Brunel University staff who are also authorised users of the CUBIC facility.

Centre for Cognition and Neuroimaging Brunel University Uxbridge UB8 3PH ccni@brunel.ac.uk

APPENDIX M (continued)



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ccni

Combined Universities Brain Imaging Centre, Royal Holloway, Egham, Surrey

INFORMATION SHEET

These notes give some information about an fMRI study in which you are invited to take part.

FMRI is a method for producing images of the activity in the brain as people carry out various mental tasks. It involves placing the participant inside a large, powerful magnet which forms part of the brain scanner. When particular regions of the brain are active, they require more oxygen, which comes from red corpuscles in the blood. As a result, the flow of blood increases. This can be detected as changes in the echoes from brief pulses of radio waves. These changes can then converted by a computer into 3D images. This enables us to determine which parts of the brain are active during different tasks.

As far as we know, this procedure poses no direct health risks. However, the Department of Health advises that certain people should be NOT be scanned. Because the scanner magnet is very powerful, it can interfere with heart pacemakers and clips or other metal items which have been implanted into the body by a surgeon, or with body-piercing items. If you have had surgery which may have involved the use of metal items you should NOT take part. You will be asked to remove metal from your pockets (coins, keys), remove articles of clothing which have metal fasteners (belts, bras, etc), as well as most jewellery. Alternative clothing will be provided as necessary. Watches and credit cards should not be taken into the scanner since it can interfere with their operation. You will already have been asked to complete a questionnaire (the Initial Screening Form) which asks about these and other matters to determine whether it is safe for you to be scanned. In addition, you are asked to give the name and address of your Family Doctor. This is because there is a very small chance that the scan would reveal something which required investigation by a doctor. If that happened, we would contact your doctor directly. By signing the consent form, you authorise us to do this. You will also be asked to complete a second, shorter, screening form immediately before the scan.

To be scanned, you would lie on your back on a narrow bed on runners, on which you would be moved until your head was inside the magnet. This is rather like having your head put inside the drum of a very large front-loading washing machine. The scanning process itself creates intermittent loud noises, and you would wear ear-plugs or sound-attenuating headphones. We would be able to talk to you while you are in the scanner through an intercom. If you are likely to become very uneasy in this relatively confined space (suffer from claustrophobia), you should NOT take part in the study. If you do take part and this happens, you will be able to alert the experimenters by squeezing a 'panic button' and will be removed from the scanner quickly. It is important that you keep your head as still as possible during the scan, and to help you with this, your head will be partially restrained with padded headrests. We shall ask you to relax your head and keep it still for a period that depends on the experiment but may be more than one hour, which may require some effort on your part. If this becomes difficult, you may ask to be removed from the scanner.

You will be asked to look at the centre of a screen through a small mirror (or other optical device) placed just above your eyes. You may be asked to make judgements about what you see or asked to perform some other kind of mental task. Details of the specific experiment in which you are invited to participate will either be appended to this sheet or else given to you verbally by the experimenter. Detailed instructions will be given just before the scan, and from time to time during it.

The whole procedure will typically take about 1 hour, plus another 15 minutes to discuss with you the purposes of the study and answer any questions about it which you may raise. You would be able to say that you wished to stop the testing and leave at any time without giving a reason. This would not affect your relationship with the experimenters in any way. The study will not benefit you directly, and does not form part of any medical diagnosis or treatment. If you agree to participate you will be asked to sign the initial screening form that accompanies this information sheet, in the presence of the experimenter (or other witness, who should countersign the form giving their name and address, if this is not practical). It is perfectly in order for you to take time to consider whether to participate, or discuss the study with other people, before signing. After signing, you will still have the right to withdraw at any time before or during the experiment, without giving a reason.

The images of your brain will be held securely and you will not be identified by name in any publications that might arise from the study. The information in the two screening forms will also be treated as strictly confidential and the forms will be held securely until eventually destroyed.

Further information about the specific study in which you are invited to participate may have been appended overleaf, if the experimenter has felt that this would be helpful. Otherwise, he/she will already have told you about the study and will give full instructions prior to the scan. Please feel free to ask any questions about any aspect of the study or the scanning procedure before completing the initial screening form.

Centre for Cognition and Neuroimaging   Brunel University   Uxbridge UB8 3PH   ccni@brunel.ac.uk

APPENDIX N: Chapter 6 Participant Information Sheet

Investigating the Effects of Music on Muscle Activity

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Participant Information Sheet

Thank you for agreeing to take part in this research project. Please note the following important information:

- Your involvement in the research project is completely voluntary
- You are entirely within your rights to withdraw from the project at any time, to no personal disadvantage
- All information you provide will be treated as strictly confidential
- You will remain completely anonymous both during and after the project

Below is a brief summary of what you can expect to do in this project:

1. Sit in a chair while a strong magnet is held to your head. This magnet can briefly stimulate the part of your brain responsible for making movements by delivering a very short magnetic pulse that feels like being tapped on the head. It will cause the muscles in one side of your body to contract briefly; this is exactly what is supposed to happen, and is perfectly normal.
2. A series of magnetic pulses will be delivered for approximately 6 minutes, on three separate occasions:
    a. While you sit in silence;
    b. Again, while you sit in silence
    c. While you listen to some loud music
3. After each of the stimulation periods above, you will perform a reaction time task that lasts about 30 seconds.
4. Two electrodes will be attached to the front of your upper arm throughout your participation in the study; these are recording electrical activity in your muscles.

If you have any questions, please do not hesitate to contact me, either via e-mail (daniel.bishop@brunel.ac.uk) or on my mobile phone: [redacted].
Thank you for your assistance!

Dan Bishop

APPENDIX O: Participant Consent Form (universal)

Consent Form

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WEST LONDON

	Please circle as appropriate	
Have you read the Participant Information Sheet?	Yes	No
Have you had an opportunity to ask questions and discuss this study?	Yes	No
Have you received satisfactory answers to all your questions?	Yes	No
Do you fully understand what the study involves?	Yes	No
Do you understand that you are free to withdraw from the study:		
• at any time?	Yes	No
• without having to give a reason for withdrawing?	Yes	No
Do you consent to take part in this study?	Yes	No

Signature of Participant………………………………………….Date……………..

Name in capitals…………………………………………………………………..

Witness Statement

I am satisfied that the above-named has given informed consent.

Witnessed by……………………………………………………….Date………………

APPENDIX P: Chapter 3 Participants' Full Demographic Details

ID	LTA	Age	Gender	Years playing tennis	Group
1	2.1	19.00	M	**8**	Full-time
2	2.1	23.00	M	**13**	Full-time
3	2.2	18.00	M	**7**	Full-time
4	2.2	18.50	M	**8**	Full-time
5		18.50	M	**7**	Full-time
6	3.1	17.50	M	**5**	Full-time
7	3.1	16.00	F	**6**	Full-time
8	4.1	18.00	F		Scholarship
9	4.1	17.75	F	**6**	Scholarship
10	3.1	16.50	F	**5.5**	Full-time
11	5.1	17.00	M	**6**	Scholarship
12	5.1	20.50	F		Scholarship
13	4.1	16.25	F	**5**	Scholarship
14	2.1	21	F	**12**	Full-time

APPENDIX Q: Chapter 4 Participants' Full Demographic Details

Participant no.	Date of birth	Age	Gender (1 = M, 2 = F)	Rating	Ethnicity	Months of competitive tennis	Left- or right-handed (1 = L, 2 = R)	Full or part time (1 = FT, 2 = PT)
1	03/06/1990	16.09	1	6.2	White UK	51	2	2
2	02/12/1987	18.59	2	3.2	White UK	108	2	1
3	09/01/1989	17.48	2	4.1	White U.S.	72	2	2
4	01/03/1987	19.35	1	2.2	Ukrainian	156	2	1
5	11/11/1991	14.65	2	9.2	Black UK	41	2	2
6	01/08/1987	18.93	1	1.2	Greek	68	2	1
7	07/05/1988	18.16	1	5.1	White UK	84	2	2
8	20/11/1989	16.62	2	5.2	White UK	72	2	2
9	29/05/1992	14.10	1	5.2	White NZ	72	2	2
10	07/03/1993	13.33	2	6.2	White UK	24	2	2
11	08/08/1988	17.91	1	9.2	White UK	48	2	2
12	19/07/1990	15.96	1	6.2	White NZ	120	2	2
13	22/09/1988	17.78	1	4.2	White UK	84	2	1
14	23/08/1989	16.87	1	6.1	White UK	30	2	2
15	10/06/1990	16.07	1	4.2	White UK	144	2	1
16	14/08/1988	17.89	2	1.1	White UK	72	2	1
17	16/06/1990	16.05	1	5.2	White UK	66	2	2
18	20/03/1986	20.30	1	2.2	White UK	120	2	1
19	31/10/1990	15.68	1	5.1	French	60	2	2
20	25/08/1989	16.86	1	4.1	Black African	45	2	1
21	22/12/1988	17.53	1	3.2	White UK	60	2	1
22	02/11/1988	17.67	1	3.1	White UK	132	2	2
23	10/09/1986	19.82	1	2.2	White UK	120	1	1
24	12/11/1990	15.64	2	3.2	White UK	90	2	2
25	07/07/1984	22.00	2	1.1	White UK	84	2	1
26	30/07/1988	17.93	1	2.2	Ukrainian	84	2	1
27	23/12/1984	21.53	1	2.2	White UK	138	2	1
28	15/09/1984	21.81	2	5.1	White UK	132	2	2
29	23/06/1987	19.04	1	2.2	White UK	121	1	1
30	19/03/1992	14.29	2	5.1	Greek Cypriot UK	64	2	2
31	02/11/1987	18.67	1	3.1	White U.S.	127	1	1
32	25/07/1988	17.95	1	3.1	White UK	96	2	1
33	24/07/1987	18.95	2	3.1	White UK	128	2	1
34	01/08/1985	20.93	1	4.2	Sri Lankan UK	120	2	1
35	17/02/1989	17.38	2	2.2	White UK	108	2	1
36	03/06/1992	14.08	2	5.1	White UK	50	2	2
37	01/07/1989	17.01	1	3.1	Lebanese	72	2	1
38	15/08/1983	22.89	1	5.1	French	144	2	1
39	22/02/1987	19.37	1	2.1	White UK	94	2	1
40	04/10/1987	18.75	1	5.1	White UK	72	2	1
41	05/12/1991	14.58	2	7.1	Moldovan	46	1	2
42	10/12/1986	19.57	2	3.2	White UK	108	2	1
43	07/04/1986	20.25	1	2.1	White UK	120	1	1
44	07/12/1987	18.58	2	5.1	White UK	72	2	2
45	31/10/1989	16.68	2	7.1	Greek Cypriot UK	60	2	2
46	05/10/1989	16.75	2	7.1	White UK	48	2	2
47	16/07/1988	17.97	2	9.2	Slovakian	96	2	2
48	11/01/1988	18.48	2	7.1	White UK	84	2	2
49	17/08/1989	16.88	1	8.2	White UK	45	2	2
50	30/09/1991	14.76	1	6.2	Turkish	36	2	2
51	16/05/1988	18.14	1	4.2	White UK	96	2	1
52	27/08/1987	18.86	1	5.1	White UK	108	2	1
53	26/06/1990	16.02	1	4.1	White UK	48	2	2
54	08/10/1990	15.74	2	5.1	White UK	38	2	2

APPENDIX R: Chapter 5 Participants' Full Demographic Details

Participant no.	Date of birth	Age	Gender (1 = M, 2 = F)	Rating	Ethnicity	Months of competitive tennis	Left- or right-handed (1 = L, 2 = R)	Full or part-time (1 = FT, 2 = PT)
1	07/07/1984	22.00	2	1.1	White UK	84	2	1
2	18/09/1987	18.80	2	2.2	White French	144	2	1
3	27/08/1987	18.86	1	5.1	White UK	108	2	1
4	14/09/1983	22.81	2	1.1	Ukrainian	156	2	1
5	23/12/1984	21.53	1	2.2	White UK	138	2	1
6	10/09/1986	19.82	1	2.2	White UK	120	2	1
7	10/12/1986	19.57	2	3.2	White UK	60	2	1
8	02/12/1987	18.59	2	3.2	White UK	108	2	1
9	04/10/1987	18.75	1	5.1	White UK	72	2	1
10	06/06/1981	25.08	1	5.1	White UK	168	2	1
11	10/03/1978	28.33	2	1.1	South African	120	2	1
12	20/03/1986	20.30	1	2.2	White UK	120	2	1

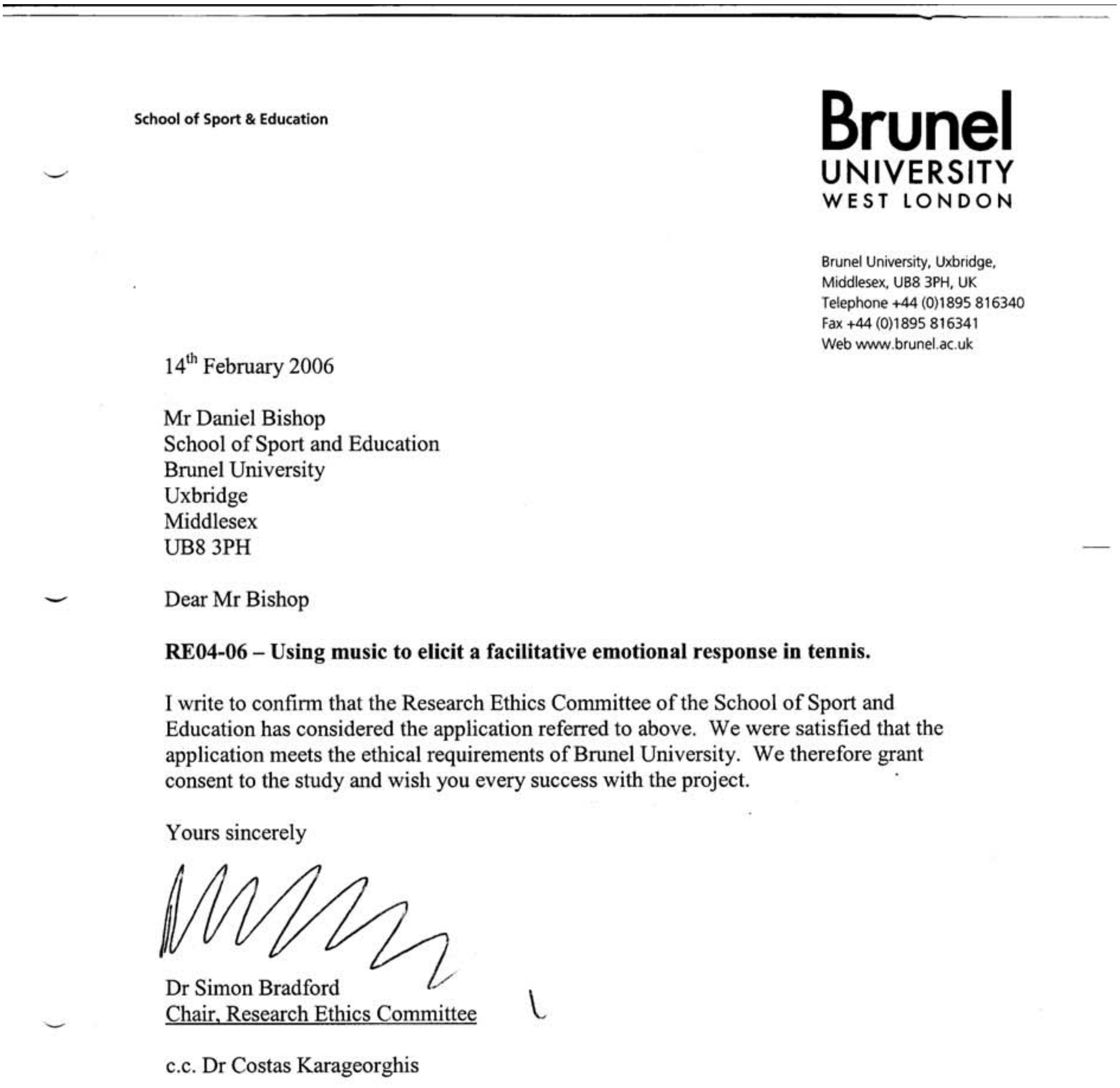
APPENDIX S: Chapter 6 Pilot Testing Participants' Full Demographic Details

Part. No.	Gender	DoB	Age	Ethnicity
27	M	24/07/1987	18.68	African English
51	M	29/11/1983	22.33	Asian
53	M	17/06/1977	28.78	Asian UK
35	M	26/05/1987	18.84	Black African
29	M	24/01/1986	20.17	Black UK
31	F	13/02/1987	19.12	Black UK
52	M	23/05/1985	20.85	Black UK
32	M	16/12/1986	19.28	Black UK
33	M	23/10/1986	19.43	Black UK
26	F	07/10/1987	18.47	Chinese
34	M	01/11/1986	19.40	Italian
50	M	03/08/1987	18.65	Middle Eastern
28	M	10/06/1986	19.80	Mixed race
57	M	13/09/1985	20.54	Moroccan
30	M	10/03/1975	31.06	Other mediterranean
14	M	05/08/1987	18.64	Somalian
63	M	30/07/1981	24.66	White Irish
64	M	18/08/1987	18.61	White Irish
65	M	01/03/1980	26.08	White Irish
5	F	22/02/1987	19.09	White Mixed
8	F	30/11/1983	22.33	White Portuguese
1	F	23/05/1987	18.85	White UK
2	F	29/07/1986	19.66	White UK
3	F	29/08/1987	18.58	White UK
4	F	18/01/1987	19.19	White UK
6	F	04/11/1986	19.39	White UK
7	M	13/09/1985	20.54	White UK
9	F	07/01/1987	19.22	White UK
10	M	27/08/1982	23.59	White UK
11	F	05/09/1986	19.56	White UK
12	F	30/12/1986	19.24	White UK
13	M	16/12/1986	19.28	White UK
15	M	12/09/1986	19.54	White UK
16	F	01/09/1986	19.57	White UK
17	F	15/09/1985	20.53	White UK
18	M	26/10/1986	19.42	White UK
19	F	12/05/1987	18.88	White UK
20	M	26/03/1986	20.01	White UK
21	F	11/05/1987	18.88	White UK
22	F	07/01/1987	19.22	White UK
23	F	24/10/1987	18.42	White UK
24	F	01/06/1987	18.82	White UK
25	F	27/04/1987	18.92	White UK
36	M	05/12/1986	19.31	White UK
37	F	17/10/1986	19.44	White UK
38	M	14/03/1987	19.04	White UK
39	M	30/07/1987	18.66	White UK
40	M	13/11/1985	20.37	White UK
41	F	12/05/1987	18.88	White UK
42	F	13/05/1987	18.87	White UK
43	M	17/07/1987	18.70	White UK
44	F	28/07/1987	18.67	White UK
45	F	08/12/1986	19.30	White UK
46	M	27/05/1987	18.84	White UK
47	M	09/06/1987	18.80	White UK
48	M	30/12/1983	22.24	White UK
49	F	08/05/1985	20.89	White UK
54	M	09/09/1986	19.55	White UK
55	F	02/11/1986	19.40	White UK
56	F	07/02/1987	19.13	White UK
58	F	26/01/1987	19.17	White UK
59	F	26/06/1987	18.75	White UK
60	F	17/10/1986	19.44	White UK
61	F	05/07/1987	18.73	White UK
62	F	22/10/1986	19.43	White UK
66	M	14/07/1987	18.70	White UK
67	M	23/01/1987	19.18	White UK
68	M	12/05/1987	18.88	White UK
69	M	06/01/1987	19.22	White UK
70	M	11/12/1986	19.29	White UK
71	M	02/06/1987	18.82	White UK
72	F	25/06/1987	18.76	White UK
73	M	27/05/1987	18.84	White UK

APPENDIX T: Chapter 6 Main Study Participants' Full Demographic Details

Participant	Date of birth	Age	Gender (1 = M, 2 = F)	Rating	Ethnicity	Months of competitive tennis	Left- or right-handed (1 = L, 2 = R)	Full or part-time (1 = FT, 2 = PT)
1	20/05/1986	20.13	1	3.1	White UK	144	2	2
2	03/03/1984	22.34	1	3.1	White UK	168	2	2
3	13/12/1978	27.57	1	3.1	White UK	132	2	2
4	08/05/1975	31.17	1	2.1	White UK	120	2	2
5	15/09/1984	21.81	2	5.1	White UK	108	2	2
6	20/10/1977	28.72	1	2.2	White UK	216	2	2
7	18/09/1987	18.80	2	2.1	French	96	2	2
8	01/03/1987	19.35	1	2.1	Ukrainian	156	2	2
9	22/02/1987	19.37	1	2.1	White UK	84	2	2
10	06/03/1986	20.33	1	1.1	Ukrainian	156	2	2

APPENDIX U: Approval Letter from Chair of Research Ethics Committee



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14th February 2006

Mr Daniel Bishop
School of Sport and Education
Brunel University
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Dear Mr Bishop

RE04-06 – Using music to elicit a facilitative emotional response in tennis.

I write to confirm that the Research Ethics Committee of the School of Sport and Education has considered the application referred to above. We were satisfied that the application meets the ethical requirements of Brunel University. We therefore grant consent to the study and wish you every success with the project.

Yours sincerely

Dr Simon Bradford
Chair, Research Ethics Committee

c.c. Dr Costas Karageorghis