EFFECTS OF VARIED MUSIC APPLICATIONS IN CYCLE ERGOMETRY

A thesis submitted for the degree of Doctor of Philosophy

By

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September 2012

Abstract

The aim of this research programme was to investigate the effects of different music applications: The differentiated exposure of music and the synchronous application of music. In Study 1, participants completed a series of 10-km cycling time trials under four single-blinded conditions: No-music control, music 0-10 km (M1), music 0-5 km (M2), and music 5-10 km (M3). The largest performance gains were noticed under M1, followed by M3, when compared to control, while the most positive psychological response was observed only in M3. Study 2 further examined the notion of differentiated music exposure by incorporating both quantitative and qualitative modes of inquiry. In addition, participants were given foreknowledge of the experimental conditions. Although no performance gains were found across conditions, M3 significantly reduced perceived exertion and prevented affective decline. Qualitative findings suggest that prolonged exposure to music may have negative psychological and psychophysical consequences. The last study contrasted the effects of synchronous and asynchronous application of music in a 6-min submaximal cycling task. Synchronous music was more effective than asynchronous music in terms of reducing perceptions of exertion and increasing subjective arousal. Although no changes in oxygen uptake were found across conditions, auditory-motor synchronisation appeared to reduce heart rate. The contribution of this thesis is twofold. Firstly, the provision of music in the latter stages of a task appears to have significant psychological and psychophysical benefits when compared against constant music exposure. Secondly, more positive effects, in terms of perceived exertion and subjective arousal, are observed when music is applied synchronously compared to asynchronously; this suggests a need for a separate conceptual framework for the application of synchronous music.

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Acknowledgements

After 4 years and 7 months, my PhD journey has finally come to an end. There have been many high and low points throughout this period of time. Physically, mentally, and in particular emotionally, I have been tested to the very limit. Nonetheless, I have managed to emerge from this great rollercoaster ride in one piece, and more importantly, with my sanity intact (although I am sure some may beg to differ!). One thing I know for certain is that I would not have been able to complete this journey without the love, support, and guidance of family members, loved ones, and friends, all of whom I owe a debt of gratitude to.

First and foremost, to my supervisors Drs Costas Karageorghis and Daniel Bishop, thank you for giving me the opportunity to undertake this PhD, and for believing in me, even through the times when I doubted myself. The completion of this thesis would not have been possible without your excellent guidance and supervision. Many a time I have gone into meetings with either of you confident in the work I produce, only to leave with more doubts and a manuscript covered in comments. Nevertheless, I am very grateful to the both of you for constantly challenging me and ensuring that I maintain the high standards that you have set. I hope that I have lived up to your expectations.

To my family, especially Mum and Dad, I am extremely grateful for the love and support that you have given me all my life, but more so over the last 5 years. I finally did it, and I hope I have done you proud. I know I don’t say this often enough, but I love you both, and feel blessed to be your son. Also to my eldest brother, Jerry, thank you for letting me “squat” in your apartment over the last 3 years. You have no idea how much it means to me! I sincerely apologise for affecting your lifestyle and routine. Hopefully I will move out sooner rather than later now that I am done!

To Michelle, thank you for loving me, and for walking more than half of this journey with me for the past 2.8 years. Knowing you were there for me, even though not physically, was a constant source of comfort and reassurance that I turned to during the tough moments in my PhD programme. I am truly sorry that I took a year more than I initially promised. Whatever happens here on in, I will always love you, and I hope you find the happiness you deserve.

To Zhen, your friendship over the last 7 years has been invaluable. Your wisdom, encouragement, and nagging have played a big part in getting me to where I am now. To Melvin, without your codes and spreadsheets, my data analyses would have been an enormous task. And not forgetting your belief in me as well. Thank you both for being such awesome buddies.

A mention must also be made to my PhD colleagues, members of staff, and administrative personnel that I have had the privilege to work beside or with. Thank you all for helping me in one way or another. Special thanks go out to Christina, Glen, and Nicola for the coffee breaks and constant reminders that I am not alone in this wretched PhD journey!

I have many more people I would like to thank and acknowledge, but given that I have written about 330 pages for the main body of this thesis, I think it is best I keep the acknowledgements short and sweet! On that note, to the people who I might have inadvertently left out, thank you all from the bottom of my heart.

Chapter 1: Introduction to the Research Programme

Oh if someone writes a song with a simple rhyme
Just a song where its feeling show
And if someone feels the same about the simple song
Oh sometimes you can hear them sing
Music gives you happiness or sadness
But it also, also heals your soul
Chorus
Let the music heal your soul
Let the music take control
Let the music give you the power to move any mountain
Oh if someone plays piano with some simple chords
So melodic and endearing too
Oh if someone plays guitar with the old piano
And maybe you can hear them sing
Music gives you happiness or sadness
But it also, also heals your soul

These lyrics are those of the pop song *Let the Music Heal Your Soul* released in May 1998 for a charity project. The words illustrate the commonly held perceptions on the varied potential of music to evoke emotion ("music gives you happiness or sadness"), as a therapeutic agent ("heals your soul"), and a motivational tool ("power to move any mountain"). A brief examination of history and mythology reveals that the numerous effects of music evident in modern society were evident many centuries ago. There are many fables and historical accounts of the potential power of music.

1.1 Music in Mythology and Antiquity

In ancient battles, pipes, trumpets, drums, and flutes were viewed as a part of a soldier’s arsenal of weapons. From 1100 BC until their defeat to the Persians, the Assyrians, who once controlled a vast empire stretching from Egypt to Anatolia, purportly danced to the melody of their war-pipes, and blood flowed wherever the pipes were heard (Martens, 1925). The Spartans, considered one of the elite military forces in history, reputedly had music flowing through their veins. To them, music was meant to “inflame with ardor for action, as a red rag does the bull – such was the Spartan musical ethos.” (Martens, p. 211). The Chinese fairytale of “The Music of Destruction” tells the story of a musical mode, the Tsing Kiao mode, which when played, would gather the demons and spirits, bringing with them misfortune (Martens, 1922).

Music not only invokes heated passion, it also has the capacity to calm the mind and soul. This point was clearly articulated by Edmondstoune Duncan (1914), “thus if its fiery air was a sword, its peaceful notes were a buckler” (p. 572). In the biblical account of David and Saul, King Saul was relieved of his immense depression through hearing David’s harp playing. The traditional Mali regards the use of a calming and stabilising musical rhythm as a revered healing agent for both individual and society (Diallo & Hall, 1989, pp. 79-80). During and after World War II, physicians were known to play music to allay the fears of shell-shocked soldiers, and to serve as a distraction from pain to those recovering from surgery (Roth & Wisser, 2004). Another unique characteristic of music can be gleaned from these historical and mythological perspectives. It would not be wrong to assume that music transcends racial, religious, and cultural boundaries, capable of reaching out to anyone, regardless of their background.

1.2 Music in Society

In modern western society, music has become almost ubiquitous in everyday life. It has become increasingly accessible due to the proliferation of the mass media during the 20th century, and much more so in the past decade as personal digital technology continues to advance apace. The portability and availability of music has meant that it is possible to make use of it in different situational contexts, for a wide variety of functions (North, Hargreaves, & Hargreaves, 2004). For example, Milliman (1982) found that background music affected supermarket shoppers such that they tended to move less quickly through the store, and were spending more money when slow music was played. In 1997, New Labour made a great deal of use of popular music as part of their image construction. D:Ream's track *Things Can Only Get Better*, was played in conjunction with New Labour's campaign strategy of promised national renewal. The context of sport and exercise is another domain where the application of music is widespread and common, and this area has attracted significant amount of interest over the last decade or so.

1.3 Music in Sport and Exercise

Research into the psychophysical and ergogenic effects of music within a sport and exercise context dates back to the beginning of the 20th century, when MacDougall (1902) suggested that music is a stimulus that encourages natural movement. The use of music as a technique to enhance psychophysical states and performance has been used by numerous athletes and sports practitioners to good effect (see Karageorghis & Terry, 2009 for review). A classic example involves the prolific Ethiopian athlete, Haile Gebrselassie, who has set 26 world records during his career. In February 1998, he smashed the indoor 2000 m record, clocking a time of 26:22.75 min, by apparently synchronising his stride rate to the tempo of the rhythmical pop song, *Scatman* (Karageorghis, 2008). American swimming sensation, Michael Phelps, winner of eight Olympic gold medals at the 2008 Games, was widely reported to listen to rap music such as DMX's *Party Up* and MAC 10's *Connected For Life* before each race in order to achieve his zone of optimal functioning. The anthem, *You'll Never Walk Alone*, recorded by Gerry and the Pacemakers in the early 1960s, has become synonymous with Liverpool Football Club (LFC), one of the giants of the soccer world. The simultaneous recital of this anthem by 30,000 plus supporters at Anfield (home of LFC) creates an electrifying atmosphere, which was acknowledged by many commentators and pundits to have played a crucial part in LFC claiming their fifth European Champions League Trophy in May 2005.

It is clear that music is rapidly becoming an important facet of sport and exercise, being broadcast in gymnasiums, stadiums, and even in swimming pools (Karageorghis, 2008). The advent of portable music devices such as the *iPod*, mp3 and CD players has made music almost omnipresent, providing potential listeners with unprecedented accessibility. In contemporary society, musical accompaniment is no longer viewed as a luxury, but a necessity by many athletes and exercise participants. More recently, Nike and Apple, two iconic, global brands in sport/exercise and portable music devices respectively, collaborated to launch *Nike+iPod*, an innovative product that utilises a special sensor implemented in running shoes to communicate with the *iPod*. The sensor is a sensitive accelerometer that measures an individual's activity, and the data is then wirelessly transmitted to the receiver on the i*Pod*. One of the unique features of this programme is that it allows users to programme the *iPod* to play specific tracks at certain distance or time points throughout their workout. The product has been a phenomenal global success, marrying the elements of music seamlessly into sport and exercise.

1.4 Statement of the Problem

Most of the literature to date has examined the psychological, psychophysical, psychophysiological, and ergogenic impact of music (see Karageorghis, 2008, for review). Early research was plagued by methodological limitations and an atheoretical approach, which may have accounted for the inconsistent findings (Karageorghis & Terry 1997). The development of a theory, extant conceptual framework, and measurement tools for assessing the motivational qualities of music (Karageorghis, Terry, & Lane, 1999; Karageorghis, Priest, Terry, Chatzisarantis, & Lane, 2006) since then have contributed to empirical work of higher quality. Researchers who have employed the guiding conceptual framework and adhered to the methodological recommendations advanced by Karageorghis and Terry have generally found positive results pertaining to the benefits associated with music listening (e.g., Crust & Clough, 2006; Elliot, Carr, & Orme, 2005;

Hutchinson et al., 2010; Simpson & Karageorghis, 2006), significantly increasing our understanding for its effects in sport and exercise contexts.

Despite such progress, there are specific areas in which research has been limited, or virtually non-existant. For example, in a series of vigilance studies (Lucaccini, 1968), it was shown that the intermittent presentation of music improves stimulus detection rates. Intuitively, one would expect the sporadic exposure of music could potentially have similar effects when applied in a sporting or exercise context, yet no research of such nature exists. Further, the existing conceptual frameworks (Bishop, Karageorghis, & Loizou, 2007; Karageorghis et al. 1999; Terry & Karageorghis, 2006), although a valuable reference point for research over the past 10 years, are limited in their capacity to explain the phenomena observed in more recent research involving self-paced experimental protocols (e.g., Atkinson, Wilson & Eubank, 2004; Lim, Atkinson, Karageorghis, & Eubank, 2009), and synchronising movement to music (e.g., Bacon, Myers & Karageorghis, 2012; Terry, Karageorghis, Saha, & D' Auria, 2012). In addition, there is a need for a paradigm shift towards more externally valid tasks because ultimately, research findings has to be applicable in the real world (Atkinson et al.).

1.5 Aims of the Research Programme

The aims of the present programme of research are focused on the effects of manipulating music exposure and the synchronous versus asynchronous application of music on cycling tasks. The decision to employ the exercise modality of cycling was in order to facilitate comparison of findings with previous studies of a similar nature (e.g., Atkinson et al., 2004;

Lim et al., 2009). Nonetheless, there were several other factors that were taken into consideration in making that decision.

Like running, cycling is a movement that the majority of individuals would have little problem with, and thus minimal training is required in familiarising participants to the task. For self-paced exercise protocols conducted in laboratories, cycling is a task that not only affords stricter control compared to running on a treadmill, but is also more reflective of reality. For instance, participants can change gears easily on stationary ergometers that mimic a proper racing bicycle, whereas on a treadmill individuals would have to press buttons to adjust running speeds. Moreover, the monitoring of pedal frequency is less tedious in comparison to stride frequency, as most cycling ergometers automatically registers pedal rates; researchers would have to video the entire exercise bout and mathematically work out stride frequency when running on a treadmill.

The first two studies are an investigation into the effects of differentiated music exposure on participants undertaking a 10-km cycling time trial. These experiments are an extension of previous work done by the author (Lim et al., 2009) that also investigated the same research question. This line of research delves into a domain that is wholly unexplored in the realm of sport and exercise. Previous findings seem to indicate that presenting music in a different manner affected participants’ pacing strategies in a 10-km cycling time trial, and it seemed that these changes cannot be wholly explained by extant research. The authors proposed that this peculiar observation can, in part be explained by *the Central Governor Model of Fatigue* (Noakes, St Clair Gibson, & Lambert, 2005). However, the study was exploratory in nature, and suffered from several limitations that might have confounded results. Accordingly, the first and second studies in this doctoral programme will seek to address these limitations while expanding upon this particular research area.

The last experiment in the thesis attempts to establish if differences exist between synchronous and asynchronous music applications. Additionally, a conceptual proposition was raised as a possible explanation for the ergogenic effects associated with the synchronous use of music. Currently, the body of knowledge and the theoretical frameworks (e.g., Bishop et al., 2007; Karageorghis et al., 1999; Terry & Karageorghis, 2006) are inadequate in explaining the findings reported in extant synchronous music research (Anshel & Marisi, 1978; Bacon et al., 2012; Simpson & Karageorghis, 2006; Terry, Karageorghis, Saha, & D'Auria, 2012). Further investigation is required to uncover the mechanisms behind these results. A possible explanation for the link between music-movement synchrony and improved performance may lie in the refinement of movement kinematics associated with keeping strict time with music (Kenyon & Thaut, 2003); this study would seek to establish if such a proposition is indeed a viable theory to substantiate findings observed with the synchronous use of music.

1.6 Operational Definitions

Key terms relating to musicology and sport and exercise psychology that regularly appear throughout this thesis are operationally defined to facilitate a full understanding.

Affect: The subjective component of an emotional response to a stimulus which is accessible to an individual’s consciousness, possessing both valance (positive or negative) and intensity/perceived arousal (strong or weak) (Russell & Feldman-Barrett, 1999).

Age-congruent music: Music which corresponds and emanates from the music listening experiences of an individual during their formative years (Karageorghis & Terry, 1997).

Arousal: Or activation, is the general bodily reaction associated with emotional changes, or physical activity, rest, and alertness (Thayer, 1996, p. 46).

Asynchronous music: Application of music in the background to accompany sport/exercise-related activities where there is no conscious attempt from the individual to match their movements with the rhythmical qualities of the music (Karageorghis, 2008).

Emotion: A state of readiness associated with a range of changes in the body, both physiologically and psychologically, in anticipation for action (Oatley & Jenkins, 1996, p. 130).

Extra-musical association: Extrinsic information that is evoked in response to certain musical pieces or segments thereof. Such associations typically pertain to personal or collective cultural experience and may provide a channel for the emotional response to music.

Harmony: A musical term referring to the simultaneous combination of three or more different pitches (Toch, 1977).

Intensity: The volume or magnitude of sound, typically measured using a decibel meter.

Melody: A succession of notes forming a distinctive expressive sequence.

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

Oudeterous: Greek word operationalised to denote the absence of both motivational and demotivational qualities in music (Karageorghis, Terry, & Lane, 1999).

Perceived Exertion: The subjective estimation of effort based upon Borg's (1998) gestalt conceptualisation of perceived exertion; physiological and psychological factors are thought to be equally important in determining one's perception of effort.

Pitch: The frequency of sound; that is, whether a sound is played in a high (treble) or low (bass) register.

Preference: A set of values acquired by experience and prior exposure but also based on innate personal differences in appreciation. Music preference is expressed as a behavioural choice. Further, such preferences are relatively constant and independent of temporary physiological and psychological changes (Jost, 1982, as cited in Schulten, 1987, p. 246).

Rhythm: The feature of music relating to the periodical accentuation and distribution of notes.

Sociocultural background: The specific mode of nurture each individual receives resulting from the social forces that he or she is exposed to during upbringing.

Synchronous music: An application of music in which there is conscious synchronisation between the rhythmical components of music (e.g., tempo) and an individual’s movement patterns (Karageorghis, 2008).

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

Chapter 2: Review of Literature

The present research programme sought to examine the effects of carefully selected music on affective responses, perceived effort, and various physiological and performance indices in sport and exercise. Given that the main research focus is on the influence of music, it is necessary first to understand how music affects an individual at the most basic psychological level. Therefore, relevant constructs such as emotion, mood, core affect, and motivation are briefly evaluated in the early stages. This is followed by a discussion on music and its effects in a variety of contexts. The penultimate section of the review is centred on music in sport and exercise, detailing potential mechanisms that might explain its effects when applied synchronously and asynchronously. A rationale for the current programme of research will then be detailed to conclude the chapter.

2.1 Emotion

Emotion constitutes a large component of the psychological make-up of human beings; it is embedded in our evolutionary and personal developmental histories, permeating most aspects of human behaviour and expression (Oatley, 2004; Sloboda & Juslin, 2001). Yet for something so pervasive and integral, it is somewhat surprising to learn that there has been no general consensus on what defines an emotion (Frijda & Scherer, 2009), more so when one considers the study of emotion has a long history; Charles Darwin's *The Expression of the Emotions in Man and Animals* (1872/2009) is widely acknowledged to be the first seminal piece of work written on emotions (Oatley & Jenkins, 1996).

The first person who attempted to define emotion was William James (1884); he theorised that emotions were the consequences of one’s perception of bodily changes that occurred in response to a stimulus. In his view, the bodily responses precede the emotional experience (e.g., we feel afraid because we run/tremble, or we feel anxious because we are tensed; Moors, 2009). James’s theory was challenged by Cannon (1927), who observed that emotions could still manifest independent of visceral changes, and that artificially inducing physical arousal via the injection of adrenalin did not elicit emotions. In addition, Cannon argued that bodily responses that supposedly occur in tandem with certain emotions lack specificity; elevations in heart rate are associated with both anger and fear, yet these emotions are distinct from each other.

Many researchers have since attempted to provide alternative theories of emotion. Some researchers contend that cognition or appraisal is the most important factor in determining whether an emotion is elicited (e.g., Frijda, 1986; Izard, 2009; Lazarus, 1991; Oatley & Johnson-Laird, 1987), while others have proposed that physiological and somatic responses are key in distinguishing emotions (e.g., Ekman & Davidson, 1994; Ekman, Davidson, & Friesen, 1990). In more recent times, researchers have looked into the dimensions of valence and activation (e.g., Carver, 2001; Russell & Feldman-Barrett, 1999; Watson, Wiese, Vaidya, & Tellegen, 1999), and neural correlates (e.g., Lang, 2010, Panksepp, 2003) to distinguish emotions. Nonetheless, despite considerable progress over the last decade, there is no universally accepted consensus on the definition of emotion (Frijda & Scherer, 2009). Izard (2009) offered a possible reason for this lack of agreement; he suggested the complexity in reaching a definition stems from researchers misinterpreting emotion as a singular phenomenon or process, a view shared by Russell and Feldman-Barrett, who stated that “emotion is too broad a class of events to be a single scientific category.” (p. 805). In Izard’s opinion, emotion is a multidimensional construct. Kleinginna and Kleinginna (1981) offered a definition that encompassed this multidimensionality:

> Emotion is a complex set of interactions among subjective and objective factors, mediated by neural/hormonal systems, which can (a) give rise to affective experiences such as feelings of arousal, pleasure/displeasure; (b) generate cognitive processes such as perceptually relevant effects, appraisals, labelling processes; (c) activate widespread physiological adjustments to the arousing conditions; and (d) lead to behaviour that is often, but not always, expressive, goal-directed, and adaptive. (p. 355)

2.1.1 Components of Emotions

Moors (2009) proposed that there are at least five factors – cognition, feeling, motivational, somatic, and motor – that can be considered constituents of an emotion. These five components correspond to four distinct functions; the cognitive aspect serves to evaluate and appraise stimuli, while the feeling component is linked to monitoring and regulation of the emotional experience. Mental and physical readiness are underpinned by motivational and somatic factors, and the motor component relates to the enactment of behaviour and expression. Frijda (1986) espoused a similar view, proposing that an emotion comprises four stages: (a) appraisal, (b) context evaluation, (c) action readiness, and (d) physiological changes, expressions, and actions. Remarkable similarities are evident, at least from a functional perspective, when these propositions are compared to Kleinginna and Kleinginna’s (1981) definition, possibly suggesting that there is a great deal of agreement regarding the components that make up an emotion. What emotion researchers tend to disagree upon is the component that is deemed to be central in the differentiation of an emotion.

2.1.2 Appraisal Theories of Emotions

One of the main reasons behind this disagreement is due to the variety of emotions theories that have been proposed. Often the theoretical perspective adopted by a researcher is aligned to their respective field of interest or research background; on the one hand, some researchers believe that physiological and somatic responses can be used to differentiate emotions (e.g., Cacioppo, Klein, Berntson, & Hartfield, 1993; Ekman & Davidson, 1994; Plutchik, 1994). In more recent times, emotion neuroscientists (e.g., Lang, 2010; Panksepp, 1998) have argued that emotions can be distinguished via unique neurological signatures. One the other, appraisal theorists (e.g., Frijda, 1986; Izard, 2009; Lazarus, 1991; Oatley & Johnson-Laird, 1987) maintain that cognition (conscious or unconscious) is the main component in the determination of an emotion. The aforementioned theories are just some of the many that have been propagated in the study of emotion (see Moors, 2009, for a review). Most of the emotion-related research in sport and exercise tends to adopt a cognitive approach (Ekkekakis & Petruzzello, 2000), in part due to the restrictions of current neuroimaging equipment. At present, it is not possible to use such equipment in conjunction with vigorous physical activity. Thus for the purpose of this thesis, the focus will be on appraisal theories, as they are most applicable and relevant to the research questions.

Proponents of appraisal theories (e.g. Frijda, 1986; Izard, 2009; Lazarus 1991; Oatley & Johnson-Laird, 1987; Scherer, 2009) believe that cognitive evaluation (conscious or unconscious) is the crucial factor in ascertaining whether a stimulus evokes an emotion or not, as well as the type of emotion that is subsequently elicited. In their view, cognition determines an emotion, and the remaining components are the consequences of that emotion. Indeed, Ortony, Clore, and Collins (1988) stated that "emotions arise as a result of certain types of cognitions...the physiological, behavioural, and expressive aspects of emotions seem to us to presuppose that this first, cognitive, step has already taken place." (p. 2).

Appraisal theorists suggest that each emotion is coupled with a unique appraisal pattern and that these patterns are formed by the combination of a number of appraisal variables (Lazarus, 1991; Oatley & Johnson-Laird, 1987; Stein, Trabasso, & Liwag, 1993). However, the precise quantity and quality of variables tend to be a source of disagreement among individual theories. Scherer (1999) pointed out that this problem is due to different theorists having disparate opinions on the quantity and quality of the emotions; a theory that attempts to illustrate the emotions of joy, sadness, fear, and anger will invariably require a smaller number of appraisal variables when compared to a theory trying to justify surprise, disgust, jealousy, shame, guilt, and pride. Nonetheless, there appears to be a fair degree of overlap on certain variables, such as that of *goal relevance* and *goal congruence*.

Lazarus (1991) suggested that goal relevance has to do with the value and satisfaction one attaches to a goal or concern; emotions surface only when a stimulus is judged to be of importance to the individual. For example, losing an item does not automatically provoke emotions, but if the item holds particular significance to a person (e.g., a family heirloom), one would expect to experience sadness. Moors (2009) proposed that goal relevance also dictates the intensity of an emotion; the higher the value ascribed to a goal, the stronger the emotion. Goal congruence on the other hand, determines the tone of the emotion, and can be best described as the compatibility between stimuli and goals; positive emotions are elicited when there is a match between stimulus and the goal at stake, while a mismatch causes negative emotions. Ekkekakis and Petruzzello (2000) summarised this scenario by stating that emotions only manifest when an appraisal process has occurred, during which the specific object or event is deemed to have the capability to either improve or reduce the wellbeing or survival of the person involved.

At the macro level, the purpose of emotions could be viewed as simply to facilitate the overall survival or wellbeing of an individual (Frijda, 1994). Microscopically, each component of the emotional episode serves a particular function that contributes to this overall purpose (Moors, 2009, Scherer, 2009). The cognitive element, as previously discussed, is the first step in this process, which starts with the identification of a stimulus as potentially emotive, followed by the elicitation of the required valence and intensity for the resultant emotion. Consequently, once this has been established, the corresponding action tendencies, expressions, and behaviours relevant to the emotion are executed (Ortony et al., 1988).

2.1.3 Mood

The common understanding of mood among laypeople is that it consists of background feelings that seem to linger for a period of time and more often than not, have no specific cause. According to Mendl, Burman, and Paul (2010), mood is a manifestation of the cumulative experience of a series of short emotional episodes It is firmly embedded in everyday life, and most people regard it to have some degree of significance even though they do not seem to give much thought to its exacting nature. Every now and then, moods of a high intensity seem to be able to significantly influence an individual’s feelings and their cognitive processes.

Mood is primarily a psychological manifestation, in so much as whatever is known about it stems directly or indirectly from self-report (Thayer, 1996, p. 4). It also comprises psychophysiological and biochemical processes, both of which can exert an influence. Thus, mood is viewed as a combination of these components, all of which are necessary for it to occur. On a functional level, mood can be thought of as an individual’s reactive behaviours to the view of the world or society as a whole, and their significance in it at that particular moment (Frijda, 1994). It is also commonly viewed as a disposition; an increased tendency or inclination to act in a manner that complements the prevailing affective backdrop (Lazarus, 1994; Ryle, 1949). Nowlis and Nowlis (1956) see it as “temporary tendencies to show certain characteristics under certain specified circumstances or to show them with greater or lesser likelihood under those circumstances" (pp. 352-353). In essence, mood can be regarded as the tendency to respond to a situation or stimulus in a manner congruent to the overall affective feeling.

2.1.4 Core Affect

Core affect has been referred to as "the most elementary consciously accessible affective feelings (and their neurophysiological counterparts) that need not be directed at anything." (Russell & Feldman-Barrett, 1999, p. 806). The notion of affective feelings is synonymous to the subjective feeling component of an emotion, otherwise known as the emotional experience, which has traditionally been investigated via linguistic self-report measures. Statistical analyses of these self-reported emotions, along with other forms of emotion assessment such as facial and vocal expression, often indicate that emotional experience can be defined by two fundamental dimensions: Valence (positive or negative) and arousal (weak or strong; Mendl et al., 2010; Russell & Feldman-Barrett, 1999).

The pleasure-displeasure dimension has been investigated under different names: Hedonic tone (Berlyne, 1971a), approach-avoidance (Frijda, 1986), appetitive-aversive (Panksepp, 2007). Nonetheless, these concept are broadly similar. At an individual level, pleasure is an overall perception of how well one is feeling/doing. A more specific view was provided by Batson, Shaw, and Oleson (1992):

"It informs the organism about those states of affairs that it values more than others. Change from a less valued to a more valued state is accompanied by positive affect; change from a more valued to a less valued state is accompanied by negative affect." (p. 298).

Arousal, on the other hand, can be described as perceived mobilisation or energy; it ranges from a continuum of deep sleep at the low end, all the way through to frenetic excitement at the high end, and this is considered a summary of an individual’s physiological state. Arousal fluctuates in response to a diurnal rhythm, and is also affected by other factors such as drug and food intake, physical activity, and daily events (Thayer, 1996). This dimension has also been investigated under different names: Activation (Larsen & Diener, 1992), engagement (Watson & Tellegen, 1985), tense energy (Thayer), and again distinct similarities are apparent (Russell & Feldman-Barrett, 1999). At any given moment, core affect can be seen as an amalgamation of pleasantness and activation. Even though these dimensions are considered to be independent of one another, they are perceived subjectively as one integrated feeling; any conceivable fusion of the two dimensions can transpire (Mendl et al., 2010; Russell & Feldman-Barrett).

Core affect can be represented in a two-dimensional space, with valence represented on the horizontal axis and activation on the vertical axis (Figure 2.1). The space on the right side denotes positive affective states, while the left side denotes negative affective states. These sides form what is known as the *core affective space*, and is considered a means of visualising the structure of emotional experience based on the dimensions of valence and activation. Certain emotions such as fear, joy, and sadness can be placed somewhere within this affective space, and it has been proposed that the structure of emotion forms a circumplex around these dimensions (see Section 2.1.6.1.3).

2.1.5 Differentiation between Emotion, Mood, and Core Affect

An examination of the early affective literature reveals that the constructs of emotion, mood, and affect has been utilised interchangeably to denote various psychological responses, and some psychologists have made no distinction among these three constructs (e.g., Boutcher, 1993; Brown & Wang, 1992; Plante & Rodin, 1990). Most emotion researchers agree that emotion, mood, and core affect should be distinguished conceptually from each other (Batson et al., 1992; Beedie, Terry, & Lane, 2005.; Davidson, 1994; Russell & Feldman-Barrett, 1999; Scherer, 2009), and have proposed several criteria for the conceptual separation of these affective constructs.

Beedie et al. (2005) argued that there were at least two reasons why a consensus on differentiating emotion, mood, and affect was required. First and foremost, they believed that “conceptual clarity is the bedrock of science” (p. 848), and without this clarity, it would be difficult to be certain that researchers are actually investigating what they intend to, a view shared by Batson et al. (1992). It seems highly likely that the equivocal findings reported in emotion research are a consequence of this conceptual mix-up. Their second reason was how such a conceptual distinction could be beneficial from a therapeutic viewpoint. Citing anxiety as an example, they proposed that if the emotion of anxiety was in any way distinct from an anxious mood, it was plausible that any distinguishable elements may present themselves as different antecedents or corollaries of the two affective states, and therefore require dissimilar interventions. However, the task of differentiating the three affective phenomena is made more difficult by the different criteria set across researchers, and these criteria, are more often than not aligned to an investigator’s area of interest and paradigmatic approach (Beedie et al., 2005; Davidson & Ekman, 1994).

The differentiation between core affect and the other two affective constructs is a straightforward one. Compared to emotion and mood, core affect is considered to be the most general affective state (Batson et al., 1992; Oatley & Jenkins, 1996). It is the experiential component of all positive or negatives responses, including emotions and moods (Ekkekakis & Petruzello, 2000). It is the most basic feature of any emotion and is thought to be the reason for the distinct non-cognitive characteristic present in valenced responses (Frijda, 1993). Nonetheless, core affect can be heightened to such a degree that it enters consciousness, leading to appraisal and the possible elicitation of an emotional response (Russell & Feldman-Barrett, 1999). Accordingly, Ortony, Clore, and Foss (1987) sum up the difference between core affect and emotion succinctly: “Affect is a broader construct than emotion. Any valenced judgement or condition implicates affect, whereas emotions are more specific. Consequently, our use of the word “affect” entails that all emotions are affective conditions, but not all affective conditions are emotions” (1987, p. 343). Mood, on the other hand, has been distinguished from core affect by its temporality. It has been defined as core affect experienced over a period of time, without any specific target (Russell & Feldman-Barrett, 1999).

The distinction between mood and emotion, unfortunately, is not as clear-cut. As mentioned previously, depending on research interests, several criteria have been set out to separate mood from emotion. Distinctions have been made on structural grounds such as duration and specificity of target;

Ekman (1994a) and Kagan (1994) asserted that moods typically last longer than emotions, which are briefer and more intense in nature. Moods are also proposed to be diffuse and unfocussed, thus associated with low or no action tendencies; emotions are seen as specific reactions to particular events (Beedie et al., 2005), similar to the notion of "intentionality" introduced by Frijda (1994). Facial expression is another criterion proposed by Ekman (1994) to provide a distinction between emotion and mood. He argued that emotion normally elicits a distinctive facial expression, while there are no overt facial expressions when it comes to mood. A distinction based on the functional aspect of mood and emotion has also been suggested; Davidson (1994) proposed that the main purpose of emotion is to bias action, whilst the function of mood is to bias cognition.

Employing a folk psychology theory to investigate emotion-mood distinctions, Beedie et al. (2005) had 106 participants respond to a single, open-ended question: "What do you believe is the difference between an emotion and a mood?" Results from the questionnaire were content analysed, along with 65 published works from the academic literature on emotion. Qualitative comparisons between the two data sources revealed that an identifiable antecedent was the factor most cited by non-academics (65%), and second most cited by academic researchers (31%). Emotions were deemed to be caused by explicit events whereas moods were seen as broad feelings that have no specific cause or direction. Another frequently cited distinction was that of duration, cited by 62% of researchers and 40% of respondents; mood was generally seen as more prolonged in comparison to emotion. Thus, structural components appear to be a reliable factor in differentiating emotions from moods.

2.1.6 Measurement of Affective Responses

In emotion research, there are typically three approaches that investigators have undertaken to assess affective responses in humans. One approach is to measure different patterns or consequences of expressive behaviours, such as facial and vocal expressions, and body language (Mauss & Robinson, 2009). Nevertheless, an issue with this approach is that emotions and expressive behaviours do not always go hand-in-hand. Further, expressive behaviours frequently occur without emotions because people use such behaviours in a deliberate manner to relay information to other individuals (Mauss & Robinson).

Another method of inquiry is the examination of physiological indices of emotion. This approach stems from the notion espoused by William James that emotion is essentially a perception of internal bodily changes. Researchers using this approach have measured cardiovascular variables such as heart rate, respiration, and blood pressure, or electrical activity such as electrocardiography and electroencephalography (see Cacioppo et al., 1993, for a review). However, there are problems with physiological assessments, the most salient being that autonomic alterations frequently manifest even without the presence of emotions. As a consequence, it is uncertain whether links between emotional states and physiological responses are accurately established (Sloboda & Juslin, 2001). More recently, advancements in neuroimaging technology have allowed neurophysiologists to identify distinct neural patterns associated with approach and avoidance behaviours; the amygdala for example, has been implicated as the source of subjective feelings of fear (Helmuth, 2003). Emotion neuroscientists argue that the mammalian brain model would greatly advance the understanding of emotion (e.g., LeDoux, 1996; Lang, 2010; Panksepp, 2003). This model is based on the perspective that emotion is a trait rooted in motivational neural circuits common to mammals, which has evolved in humans (Lang). Nonetheless, current brain imaging tools for humans are still undergoing refinement, and it will be some time before human imaging technologies can precisely map the exact neural structures of emotions (Lang). The last approach to examining emotional response involves the use of self-report measures.

2.1.6.1 Self-report measures. The use of self-report measures is the most common, and yet simplest, approach used in the investigation of emotion. Individuals rate their emotional state against an emotion adjective on a Likert-type scale or narrate/describe their feelings. Some examples of self-report measures include adjective checklists, rating scales, questionnaires, and free descriptions (Mauss & Robinson, 2009). There are typically two approaches researchers follow in their investigation of emotions: Categorical or dimensional. The categorical approach has traditionally been the choice for emotion research, but dimensional theories are rapidly gaining prominence. There is continuing debate between advocates of the categorical and dimensional perspectives of emotion (e.g. Feldman-Barrett, 2006; Izard 2007; Panksepp, 2007). Both approaches have their respective strengths and weaknesses, and the decision to adopt one over the other should depend on the intention of the research and the extant knowledge base (Ekkekakis & Petruzzello, 2000; Mendl et al., 2010).

2.1.6.1.1 Categorical approach. Researchers adopting this approach tend to see emotions as categories that can be clearly differentiated from each other. The key concept of a categorical perspective is the idea of basic emotions: The existence of a handful of innate and universal emotion categories that form the basis of all other emotional responses (Ekman, 1994b; Panksepp, 1994). Basic emotions can be considered as biological reflexes used to deal with emergency situations that require a quick, rather than precise response.

The most crucial criteria that define basic emotions are that they (a) possess clear functions that plays a role in human survival, (b) are evident in every culture, (c) are experienced as unique affective states, (d) manifest in early childhood, (e) are accompanied by characteristic physiological alteration patterns, (f) are deducible from higher-order species, and (g) have clear expressive behaviours (Ekman, 1992; Izard, 1977; Oatley, 1992; Panksepp, 1992). It is believed that all other emotions are either a mixture of basic emotions (Plutchik, 1994) or consist of particular cognitive evaluations that materialise in tandem with a basic emotion (Oatley).

The strength of categorical conceptualisations is the specificity and degree of precision it affords in making fine distinctions of psychological meanings (Ekkekakis & Petruzello, 2000). However, this strength can also be seen as a weakness; there are disagreements between researchers as to the quantity and validity of emotions proposed to be basic (Ekman, 1992). Further, a categorical approach assumes an individual’s emotional state would fall within these pre-determined emotion categories, which might not always be the case. Categorical models are generally applied in the examination of emotional states with similar and yet distinctively different antecedents and experiential characteristics (Ekkekakis & Petruzello).

2.1.6.1.2 Dimensional approach. The essence of a dimensional perspective is the notion that emotions are systematically interrelated and accordingly, can be identified by their placement on a small set of dimensions; core affective states can be differentiated on as little as the two dimensions of valence and activation. This constitutes the main strength of dimensional models; the breadth of scope and parsimony effectively enables it to represent the entire affective space. Nonetheless, this parsimony renders dimensional models inadequate in distinguishing qualitatively different emotions that share similar levels of valence and activation. Examples include fear, anger, disgust, and embarrassment; these emotions occupy identical placements on the dimensions of valence and activation and yet all have distinctly different behavioural and motivational consequences for an individual (Ekkekakis & Petruzzello, 2000; Russell & Feldman-Barrett, 1999). It is important to note, however, that even though categorical and dimensional perspectives are conceptually different, they are not mutually exclusive, and are rather compatible and complementary to each other (Ekkekakis & Petruzzello, 2000, 2002).

In a series of critical reviews (Ekkekakis & Petruzzello, 2000, 2001a, 2001b, 2002) regarding the examination of affect in exercise psychology, Ekkekakis and Petruzzello argued that exercise is a multidimensional stimulus capable of eliciting affective responses ranging from core affect to specific emotions. They espouse the view that a dimensional approach is the most appropriate for the study of emotions during exercise. This standpoint was adopted on the basis that little is understood of the cognitive appraisals underlying the elicitation of specific emotions in exercise contexts, and therefore a parsimonious assessment of affective responses would seem more desirable. Further, it has been suggested that a dimensional approach might be more suited for monitoring incessant changes in emotional expression evoked while listening to music (Sloboda & Juslin, 2001). Given that the current research involves the investigation of psychological responses to music during cycling, the dimensional approach proposed by Ekkekakis and Petruzzello appears to be the logical choice.

2.1.6.1.3 Circumplex model of affect. Although several dimensional models have been proposed, a commonality in most of them is the inclusion of at least two dimensions of valence (pleasure or hedonic tone) and perceived activation (arousal). These two dimensions have been argued to be bipolar and orthogonal, and form the basis of the circumplex model. In the circumplex model, emotional states are viewed as combinations of different levels of valence and activation, and are conceptualised to form a circular structure around these two dimensions (Figure 2.1). The circumplex space can be divided into four quadrants, each corresponding with a particular type of affective experience (Ekkekakis & Petruzello, 2002):

1. High-activation pleasant affect, such as excitement and delight, are placed in the top-right quadrant.
2. High-activation unpleasant affect, characteristic of affective responses such as anger and fear, are positioned in the top left quadrant.

3. Low-activation pleasant affect, corresponding to states such as misery and tiredness, are found in the bottom left quadrant.

4. Low-activation pleasant affect, indicative of affective states such as calmness and relaxation, are placed in the bottom right quadrant.

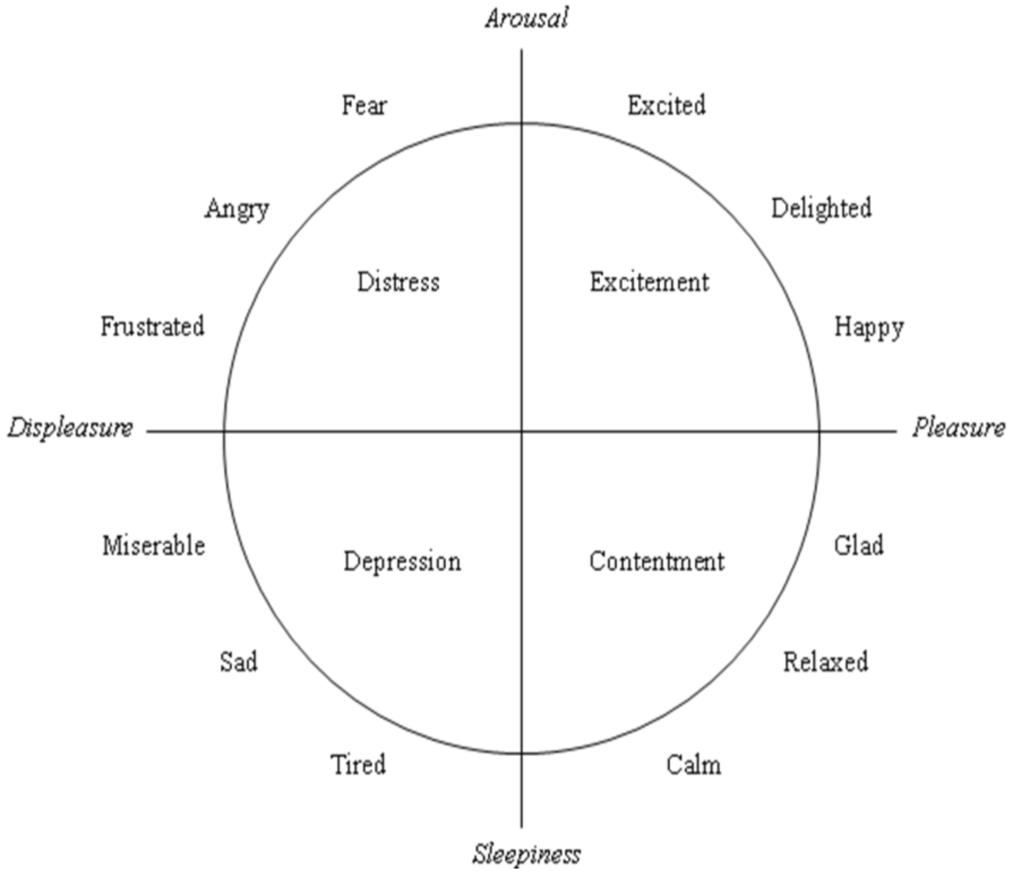

Figure 2.1. A circumplex model of affect (adapted from Russell, 1980).

There are two versions to the circumplex structure, differentiated by the rotation of the dimensions that make up the affective space (see Larsen & Diener, 1992, for a review). The above structure is the unrotated model, whereby the affective space is defined by the dimensions of valence and perceived activation. The other variant, the rotated model, is also defined by the two dimensions, but with a 45^{o} rotation, giving rise to the revised dimensions of Positive Activation (PA) and Negative Activation (NA). Even though the labels given to these rotated dimensions are an indication of their high activation poles, these dimensions are considered bipolar in nature. Positive Activation extends from high-activation pleasant to low-activation unpleasant affect whereas Negative Activation runs from high-activation unpleasant to low-activation pleasant affect (Tellegen, 1985; Watson & Tellegen 1985; 1999). There are two issues to take into account regarding rotation. Firstly, any rotation of a true circumplex structure should account for equal amounts of variance, thus the decision of which version to use would depend upon the researcher’s specific interests and purpose (Larsen & Diener). Secondly, there is a general consensus among advocates of the two variants that these structures are conceptually compatible (Russell & Feldman-Barrett, 1999; Watson & Tellegen).

There has also been suggestion of additional dimensions in the circumplex, most notably a potency dimension (Mehrabian & Russell, 1974), which provides the possibility of distinguishing emotional states. This suggestion has been largely dismissed on the basis that the additional variance accounted for by this dimension was miniscule, but the transition from a two-dimensional to three-dimensional structure would have been more complex (Ekkekakis & Petruzello, 2002). Further, if the aim is to make clear distinctions among affective states, investigators should consider the specificity offered by categorical models. The circumplex model has been supported by an extensive amount of research (Faith & Thayer, 2001; Feldman-Barrett, 1996; Haslam, 1995; Larsen & Diener, 1992; Russell, 1997), and has been successfully tested across a variety of different populations and cultures (see Ekkekakis & Petruzello, 2002, for review).

2.1.6.1.3.1 Single-item measures. The main appeal of single-item instruments lies in their simplicity; they can be used repetitively in an experiment with minimal risk of respondent overload and inducing reactivity to testing (Ekkekakis & Petruzello, 2002). Nevertheless, single-item measures are more prone to random measurement error in comparison to multi-item scales because scores are based on just one response.

The best known single-item measure is the Affect Grid developed by Russell, Weiss, and Mendelsohn (1989). Responses are made on a 9-by-9 grid, by placing a mark in one of the 81 cells available. This response corresponds with the dimensions of valence and arousal, which are represented in the grid by the horizontal and vertical axis respectively. The pleasure score is taken as the number of the column, counting from the left, where the mark is placed in, while the arousal score is the number of the row counting from the bottom. Although the psychometric properties of the AG are sound, it has not been utilised much by researchers in sport and exercise psychology, at least not during the task itself (Ekkekakis & Petruzello, 2002; Ekkekakis, Parfitt, & Petruzzello, 2011). A possible reason may relate to the fact that the Affect Grid requires a lengthy explanation about the circumplex and what it represents before it can be administered effectively. Moreover, individuals would need to be able to grasp a complex psychological concept in order to fully comprehend the explanation (Ekkekakis, 20 February 2009, personal communications). Accordingly, these factors may have detracted researchers from using the Affect Grid.

The Self-Assessment Manikin (SAM) is a computer-based interactive graphical instrument that utilises a series of cartoons depicting various visible expressions that examines valence, arousal, and dominance (Hodes, Cook, & Lang, 1985; Lang, 1980). Each scale is represented by a distinct facial expression depicted by a manikin; valence ranges from happiness (smiling face) to sadness (sad face), arousal is denoted by sleepiness (closed eyes) to high arousal (shaking and heart pounding), and dominance is characterised by a progressive increase in size of the manikin (small to large). Use of the SAM is widespread in psychophysiology, particularly in measuring responses to pleasant and unpleasant visual stimuli (e.g., Backs, Da Silva, & Han, 2005; Bradley, Greenwald, & Hamm, 1993; Herpertz, Kunert, Schwenger, & Sass, 1999; Rhudy, Williams, McCabe, Nguyễn, & Rambo, 2005). Further, Morris (1995) proposed that the SAM is suitable for cross-cultural research as it uses universally recognised facial expressions.

Researchers have also used separate bipolar scales to assess valence and activation (Ekkekakis & Petruzello, 2002). The Feeling Scale (FS; Hardy & Rejeski, 1989) and the Felt Arousal Scale (FAS) of the Telic State Measure (Svebak & Murgatroyd, 1985) are two such measures that can be used to assess affective valence and perceived activation respectively. Compared to the AG (grid) and SAM (cartoons), both the FS and FAS use a more familiar Likert-type response scale. As such, they may be easier and more convenient to administer to a large proportion of the population (Ekkekakis & Petruzello).

2.1.6.1.3.2 Multi-item measures. Mehrabian and Russell (1974) developed the Semantic Differential Scale, which comprises 18 bipolar items designed to tap the dimensions of pleasure-displeasure (P), arousal-sleepiness (A), and dominance-submissiveness (D). Researchers have reported a distinct three-factor structure and small and insignificant inter-scale correlations (Mehrabian & Russell; Russell, Ward, & Pratt, 1981). It has subsequently been revised twice to broaden the PAD scales of the Semantic Differential Scale and fine-tune their contents (Mehrabian 1978, 1995). The scale is used mainly to examine the 3-dimensional structure of situations, events, and objects (Bradley & Lang, 1994).

The structural integrity of the revised version of the Activation Deactivation Adjective Check List (AD ACL; Thayer, 1986) has also been proposed to fit well with the circumplex model. It consists of two bipolar dimensions: Energetic Arousal (EA) and Tense Arousal (TA), which are represented by 10 items each. Energy and tiredness anchor the two ends of the EA dimension, whilst the TA dimension is represented by tension and calmness. Thayer (1985) and Ekkekakis, Hall, and Petruzello (2005) have provided substantial evidence supporting the validity and reliability of the AD ACL. Their findings also suggest that the structure of the AD ACL conforms to a circumplex, at least in the context of physical activity. Items describing energy, tension, tiredness, and calmness correspond to the four quadrants of high-activation pleasure, high-activation displeasure, low-activation displeasure, and low-activation pleasure respectively.

2.2 Music

The ubiquity of music is evident in modern society; from the commuter on the train to the casual jogger pounding the streets, most of them can be seen plugged into a personal music device. Music can also be heard frequently in retail stores and on television, making its presence almost unavoidable. The widespread use of music is owed in large part, to the advancements in audio-digital and electronic technology in the 20th century, providing music consumers with unprecedented ease of music transfer and portability. The *iPod*, for instance, has become the most iconic representation of this digital music revolution; in April 2007, the parent company, Apple, announced that they had sold 100 million iPods worldwide, and proposed that the iPod was the fastest-selling music device in history. (http://www.macworld.com/article/57233/2007/04/ipodmilestone.html). However, this popularity is as much due to the company's ingenious product design as it is to its ability to deliver music. Accordingly, one could argue that the individual's need for music has contributed significantly to the iPod's success. What purpose does music serve, and why does it hold such significance? A potential answer may lie in a quote by the 19th century French poet, Victor Hugo: "Music expresses that which cannot be said and on which it is impossible to be silent". This quotation illustrates a well-described property of music; its ability to communicate (Williamson, 2009, p. 1022). It is this expressive quality that endears music to its listeners.

2.2.1 Emotional Responses to Music

The research on mainstream emotion literature rarely considers the emotional responses to music. Sloboda and Juslin (2001) put forth two reasons for this neglect. For one, emotion researchers may have assumed that the emotions elicited via music differ from the typical emotions that are experienced. This is however, not the case; although musical emotions and typical emotions do have significant differences in terms of its antecedents and consequences, this does not necessarily mean the emotions experienced are different (Sloboda & Juslin). The other reason for the lack of interest in musical emotions within mainstream emotion research may be due to perceived significance; emotion researchers could simply view emotions induced by music to be of less importance. This however, could be because mainstream emotion researchers do not see the vital role that music plays in people's daily functioning (Sloboda & O'Neill, 2001).

Musical emotions can be classed as *aesthetic* emotions (Sloboda & Juslin, 2001). Scherer (2004) defined such emotions as the appraisals of artistic qualities inherent in visual or auditory stimuli. Aesthetic emotions can be considered similar to the notion of *secondary* emotion, which are acquired/learned dispositions that arise from cognitive as opposed to perceptual phenomena, and do not serve evolutionarily adaptive purposes (Damasio, 1994). *Primary* emotions on the other hand, are concerned with the survival of the organism and are elicited through innate dispositional representations (Damasio).

2.2.2 Mechanisms for Musically-Induced Emotions

Apart from eliciting aesthetic emotions, music is also capable of inducing or expressing emotions that are more akin to those typically studied in emotion research. Scherer and Zentner (2001) identified three central routes in which emotions are produced as a result of listening to music. The memory route, whereby music functions as catalyst that initiates the recollection of an emotive episode or situation. This is possibly achieved via subcortical mechanisms that do not yield easily to neural rewiring (LeDoux, 1996). The empathy route concerns the listener's ability to discern and perceive the emotions a performer is encountering. Scherer and Zentner suggested that this is a more probable route for emotion induction when listening to a highly regarded performer, or when the music is played in an emotionally expressive manner. The final route is appraisal, wherein the listener discerns significance of a musically induced emotion in relation to his or her personal wellbeing. Two peripheral routes to musically induced emotions were also noticed by Scherer and Zentner: *Proprioceptive feedback*, whereby emotions can be generated through instigating bodily responses associated with that particular emotion, which they described as the coupling of internal rhythms to external drivers; and *facilitating the expression of pre-existing emotion*, which pertain to the relaxing of emotional control commonly displayed in social contexts (Ekman, 1972).

2.2.3 Neurocorrelates of Music Listening and Auditory-Motor Synchronisation

Employing functional Magnetic Resonance Imaging (fMRI), Menon and Levitin (2005) were able to directly identify brain structures/areas that are implicated during pleasureable music listening. Mesolimbic structures including the nucleus accumbens, ventral tegmental area, hypothalamus, and insula showed significant activation under passive music listening. Researchers have previously reported similar activations by employing positron emission topography, although spatial resolution limitations of the technique meant that specific brain structures, such as the nucleus accumbens, could not be accurately mapped (Brown, Martinez, & Parsons, 2004). Menon and Levitin’s work, was thus able to corroborate past research and at the same time, demonstrate the direct involvement of the nucleus accumbens, an area known for its role in processing reward and pleasure (Knutson, Adams, Fong, & Hommer, 2001; Robinson & Berridge, 2003).

Activation of the hypothalamus, a region that regulates autonomic responses such as heart rate and respiration, provided direct neurological evidence of the physiological responses that are normally associated with listening to pleasurable music listening such as changes in heart rate and respiration (Krumhansl, 1997).

In terms of movement-to-music synchrony, a corpus of work exists in the sensorimotor synchronisation tapping literature that have attempted to uncover the neural circuitry involved in keeping time with a rhythmic auditory stimulus (e.g., Chen, Zatorre, & Penhune, 2006; Molinari, Leggio, & Thaut, 2007; Thaut, 2003). Brain regions that have been identified include the cerebellum, primary sensorimoter area, premotor cortex, supplementary motor area, and superior temporal gyrus (Molinari, Leggio, De Martin, Cerasa, & Thaut, 2003;Thaut). The cerebellum appears to play a role in the entrainment of movement (Molinari et al., 2007; Penhune, Zatorre, & Evans, 1998), while the premotor and supplementary motor areas have been implicated in sensorimoter integration (Kurata, Tsuji, Naraki, Seino, & Abe, 2000; Zatorre, Halpern, Perry, Meyer, & Evans, 1996).

2.2.4 Sources of Emotion in Music

Sloboda and Juslin (2001) proposed that emotional responses to music can be separated into two distinct sources: *Intrinsic* and *extrinsic*. In essence, intrinsic sources of emotion are derived from the structural characteristics of music such as tempo, harmony, and intensity; whereas extrinsic sources are any other factors not concerned with the internal structure of the music itself.

2.2.4.1 Intrinsic sources of emotion. In one of the earliest experiments conducted to examine the intrinsic sources of emotion in music, Hevner (1937) presented musical compositions of various tempi and octaves to students. They were then required to select adjectives from a checklist which best described what they perceive the music was expressing. Fast tempo music evoked emotional responses such as *exciting* and *exhilarated*, while expressions of *calm* and *tranquil* were reported for musical pieces with a slow tempo. Music played in the major mode elicited responses of a more light-hearted nature, for example, *happy*, *cheerful*, and *playful* to name a few. On the other end, music in the minor mode reflected unpleasant feelings such as *depression*, *frustration*, and *melancholy*.

Sloboda (1991, 1992) were able to identify structural qualities of music that relate to certain bodily and behavioural manifestations of emotion, such as weeping or thrills (cf. Goldstein). These characteristics comprise of structures such as syncopations, enharmonic changes, melodic appoggiaturas, and other musical constructs, all of which have a close relationship to creating, maintaining, confirming or disrupting musical expectations. Moreover, emotional responses can be mediated by the interaction of structural characteristics. Webster and Weir (2005) investigated the interactive influence of tempo (72, 108, and 144 bpm), mode (major vs. minor), and texture (harmonised vs. nonharmonised) on the emotional experiences of music listening. They reported that fast tempi music played in major keys with nonharmonised melodies were associated with happier responses, whereas music with the opposite characteristics were related to sadder responses. Collectively the studies of Hevner, Sloboda, and Webster and Weir strongly indicate that the structural characteristics of music have the capacity to evoke emotional responses in listeners. In addition, these characteristics can have an interactive effect on the type of response evoked.

2.2.4.2 Extrinsic sources of emotion. Extrinsic sources refer to factors that are not associated with the inherent qualities of the music itself. These sources can be delineated into *iconic* and *associational*. Iconic sources of emotions are the result of some formal resemblance between a musical structure and some agent carrying emotional tone. An example relates to tempo and intensity; fast and loud music has certain features similar to high energy events, and may thus evoke high energy emotions such as excitement. Researchers have observed that iconic relationships may carry specific emotions that provide emotional content to the non-specific sensations arising from engagement at the purely structural level of music (e.g., Bruner, 1990; Hevner, 1935).

Associative sources of emotion in music are based on arbitrary relationships established between a particular piece of music and a host of other un-related factors that in it selves carry emotional meaning (Sloboda & Juslin, 2001). Researchers have found that specific pieces of music can be associated with particular contexts or events in the past, and act as a trigger to the recollection of such events (e.g., Gabrielsson, 1991; Sloboda, 1991). In such instances, the resultant emotions evoked are tied to the event rather than the music itself. Nonetheless, there is little scientific research available on the associative sources of emotion, mainly due to the difficulty of controlling and generalising the idiosyncrasy of such associations (Sloboda & Juslin).

Sloboda and Juslin (2001) suggested that extrinsic factors are better at distinguishing emotional valence, while intrinsic characteristics are more suited for determining the emotional intensity. They also proposed that emotional responses to music reflect both sources, and the sources could interact to evoke a variety of responses. For example, a segment of a musical piece may build up tension through musical expectations (intrinsic). This in turn may trigger a certain extra-musical context that contains feelings of tension. Thus, intrinsic and extrinsic sources are not mutually exclusive to each other.

2.2.5 Music Preference

In a review, Finnäs (1989) came to the conclusion that several elements can influence music preference: The specific components of music such as tempo and rhythm, familiarity, the emotional experiences evoked in the listener, and social influences. Other factors include the physiological state (McNamara & Ballard, 1999), personality (Rentfrow & Gosling, 2003; 2006), age of the listener (Mende, 1991), and the music listening context (North, Hargreaves, & Hargreaves, 2004). Research on music preference has mostly been investigated from an experimental aesthetics perspective. The typical methodological approach of this perspective employed the use of a short musical stimulus (i.e., 5-15 s), which was most often monophonic (one note at a time). Studies were usually conducted in strict laboratory conditions and used undergraduate students as participants. Preference was examined either by self-report or through various physiological parameters such as heart rate and galvanic skin response. This standard methodology gave researchers strict control over the musical stimulus and the immediate environment in which it was administered, as well as objective responses that were not easily distorted. Using such an approach, Gustav Fechner’s 1876 publication of “*Vorschule der Äesthetik*” established experimental aesthetics firmly in experimental psychology. He believed in the notion of the *aesthetic mean*, wherein aesthetic beauty is associated with the absence of extremes. This idea was further developed by Daniel Berlyne (1960, 1971a, 1974) into the *new experimental aesthetics*, which embraced a psychobiological perspective.

2.2.5.1 Berlyne’s aesthetic theory. In a series of experiments carried out during the 1960s and 1970s, Berlyne (1960, 1971a, 1974) investigated how the collation of stimulus variables has the potential to mediate liking for artistic stimuli such as music. He suggested that internal aspects of music such as complexity, familiarity, and redundancy can stimulate neural firing in the brainstem, hypothalamus, and reticular formation; brain areas known to be involved in arousal (Critchley, Corfield, Chandler, Mathias, & Dolan, 2000). Berlyne (1971a) advanced the notion that the arousal potential of a given stimulus is governed by four properties: (a) psychophysical properties that contain informational characteristics about the stimulus, such as tempo, intensity and pitch in music; (b) Collative properties that relate to the evaluation of informational aspects within the stimulus such as complexity and familiarity; (c) ecological properties that refer to the signal value or meaningfulness of a particular pieces of music, and (d) the arousal potential of non-focal stimuli that exist in the peripheral surroundings of the main stimulus.

Of the four properties, Berlyne (1971a) indicated that collative properties are the most important variables that affect the arousal potential of stimuli. Novelty, for example, tends to increase the probability and the duration of stimulus exposure. He also provided strong evidence of an inverted-U relationship between preferences for artistic stimuli and their arousal potential. Thus, moderately arousing stimuli are most preferred, and this preference is lower at the more extreme ends of stimulus arousal potential. This relationship has found support in empirical research (Kellaris, 1992; North & Hargreaves, 1996). Tempo is regarded as the most salient determinant of response to music (Webster & Weir, 2005), and it has been proposed that preference for a particular tempo is related to the physiological arousal of the listener as well as the musical context; when an individual's arousal is high, a faster tempo is preferred (Berlyne, 1971b; North & Hargreaves, 2008).

2.2.5.2 Sociocultural background. An individual's social status, environment, education, ethnicity, and peer influence are just some of the socio-cultural factors that can impact upon their musical choice. These factors could determine the type and kind of music that a listener is exposed to. For example, DiMaggio and Useem (1978) observed that the popular musical arts are appreciated amongst people from different socioeconomic strata in equal measure, whereas the likes of opera, symphony, and ballet appear to be enjoyed exclusively by those of higher socio-economic status. Moreover, these factors do not always exert their influence independently. Mark (1998) proposed that one's preference for music is dictated by the interaction of socio-demographic characteristics such as age, occupational prestige, education, and annual family income. It has been suggested that preference for classical music appears to reach a peak for those between 55 and 64 years, while those between 25 and 34 years of age expressed the greatest preference for soul music (Robinson & Fink, 1996). The authors also observed an interaction between the variables of age and educational status; as individuals grow older they might become more educated, and possibly improve their socioeconomic status.

2.2.5.3 Association. Personal musical experiences can be embedded into a person's memory and become associated with certain feelings and emotions, which can manifest themselves in future situations of a similar nature. For example, feelings of sadness might be elicited when a person views an object that reminds them of a lost loved one. Associations can also accrue through repeated exposure, as in the case of classical conditioning, as well as to constant media attention. Extra-musical associations for example, are significant determinants of the emotional response to music (Gabrielsson & Juslin, 1996); viewers familiar with the Rocky Balboa movie series would find tracks such as *Eye of the Tiger* and *Gonna Fly Now* particularly inspiring, given their association with striving to overcome adversity (Karageorghis & Terry, 2009).

2.2.5.4 Music listening context. Musical preferences tend to vary according to the situation and needs of the individual. Accordingly, even though one could express a fondness for a particular piece of music, it might not be appropriate for the context or might not fulfil the needs of the listener. For example, although the music chosen for a party and a romantic candlelit dinner might be equally pleasing to the user, the characteristics of such music would be vastly different. North and Hargreaves (2008) suggested that appropriateness maybe linked to how a particular piece of music is perceived as being typical of music that is usually played in that specific context. This relationship between music preference and its appropriateness for the listening context was tested in an earlier study (North & Hargreaves, 1996). Exercisers that took part in both aerobic and yoga classes rated music for liking and complexity. In addition, participants were requested to rate the appropriateness of each musical piece for a given class. Results supported the theory; appropriateness had as strong a relationship to preference as complexity.

North and Hargreaves (2000) then examined the relationship between preference and the needs of the listener via the notion of arousal-based goals. In the first experiment, participants were put into two situations of differing arousal potential: (a) riding an exercise bike (high arousal) and (b) relaxing on a bed. After going through the situations, participants were asked to select either fast, loud (i.e., high arousal) or slow, quiet (low arousal) versions of the same musical piece. Fast, loud music was selected after relaxation, while slow, quiet music was participants’ choice after cycling on the exercise bike.

In the second experiment, the situation and music was the same as the first, but participants were instead asked to choose the music they preferred to listen to while in the situation. Results were opposite of that in the first experiment; highly arousing music was preferred during cycling, and vice-versa. Taking into account the results of both experiments, North and Hargreaves proposed that participants’ goals dictated music preference. More specifically, when put in a particular situation, such as exercising on the bike, participants are likely to select music that would polarise the arousal of the given situation. In this case, riding the bike had the goal of achieving high arousal, and thus music of similar arousing potential will be selected to facilitate that goal. However, outside of that situation, the goal would change from facilitation to regulation, since there is no longer a need to maintain high arousal levels. In this instance, music of an opposing arousal nature will be chosen.

2.3 Music in Sport and Exercise

Research in psychomusicology has typically focussed on four aspects in which music is purported to have an effect on: Psychological, psychophysiological, psychophysical, and ergogenic. Psychological effects refer to music’s ability to moderate affect, cognition, and behaviour (Karageorghis & Terry, 2009). Psychophysiological effects are concerned with how music influences physiological functioning. The psychophysical effects of music relate to how an individual perceives physical effort, and are often quantified using ratings of perceived exertion (RPE). Ergogenic effects entail an increment in work output or the production of higher-than-expected levels of physical performance in response to music (Karageorghis & Terry).

The application of music as a technique to manipulate psychological and psychophysical states, and improve performances of individuals involved in sport and exercise, has often been advocated (see Terry & Karageorghis, 2006, for a review). Widespread music usage by professional athletes would seem to suggest that it is prevalent within sport. The ubiquitous presence of music in gymnasia further indicates that it is also valued by exercisers. Typically, researchers in sport and exercise have predominately investigated the ergogenic, psychophysical, and psychological effects of music (e.g. Boutcher & Trenske, 1990; Dorney & Goh, 1992; Karageorghis, Drew, & Terry, 1996; Tenenbaum et al., 2004).

2.3.1 Mechanisms

According to theorists such as Karageorghis, Terry, and Lane (1999) and latterly Karageorghis (2008), music has been hypothesised to engender these effects through three processes. First, it has been proposed that the synchronisation between music tempo and a performer’s movement can increase work output (Karageorghis & Terry, 1997). Second, music can alter psychomotor arousal, and thus be used to stimulate or sedate performers prior to, and during exercise (Karageorghis & Terry, 1997). Third, through the application of Rejeski’s parallel attentional processing model (Rejeski, 1985), researchers have indicated that attention can be channelled away from internal sensations of fatigue by focusing the performer’s attention on an external stimulus; a technique known as *dissociation* (Boutcher & Trenske, 1990; Karageorghis, 2008). Nonetheless, music seems only to exert this influence at low-to-moderate exercise intensities, where external stimuli can compete against internal cues for attentional focus. At higher intensities, internal cues dominate the psychophysical response. Music also has the potential to influence affective states, which may, in turn, have an impact on performance. Unlike the effect of music on perceived exertion, it appears to influence affective responses even at high exercise intensities (Boutcher & Trenske, 1990; Karageorghis et al., 2009; Tenenbaum et al., 2004); this is not explained by extant theory.

2.3.2 Early Research Developments

Past empirical investigations into the proposed ergogenic effects of music have been largely equivocal (see Karageorghis & Terry, 1997; Lucaccini & Kreit, 1972 for reviews). In support of the proposed effects, Copeland and Franks (1991) observed that participants exhibited higher levels of endurance when they ran to the accompaniment of music compared to a no-music control condition in a time-to-exhaustion treadmill protocol. Further support for the ergogenic effects of music has also been reported in other studies; performance of a karate drill improved following the use of positive and negative music in comparison to white noise (Ferguson, Carbonneau, & Chambliss, 1994), and higher levels of grip strength were recorded after listening to stimulative music compared to sedative music or a white noise condition (Karageorghis et al., 1996). On the other hand, there are experiments that reported none of the proposed ergogenic effects of music. For example, Dorney and Goh (1992) observed that there was no significant performance improvement in their investigation of the impact of music on a dart-throwing task. Pearce (1981) showed that listening to stimulative music had no effect on grip strength compared to silence, while listening to sedative music reduced performance levels compared to the other two conditions.

Support for the psychophysical effects of music was also largely inconsistent. Ratings of perceived exertion (RPE) were lower when participants were exposed to music compared to a control and sensory deprived condition in a cycle ergometer task at light and moderate workloads (Boutcher & Trenske, 1990). Employing a treadmill running protocol, Copeland and Franks (1991) found that individuals listening to soft/slow music during moderate workloads reported lower levels of RPE. Nonetheless, some researchers have found that music did not influence RPE to any degree when compared to a no-music condition; White and Potteiger

(1996) tested the effects of various distractions, one of which was upbeat music (140-145 bpm), on perceived exertion during a low- intensity cycling task. Little differences were observed between the control and music conditions. Similarly, Schwartz, Fernhall, and Plowman (1990) found that untrained participants reported no significant differences in RPE between stimulative music and a control condition while cycling at 75% $\dot{V}O_{2max}$, although in this instance, the relatively high exercise intensity may have rendered the distractive effects of music useless (Rejeski, 1985).

Early researchers investigating the psychophysiological responses to music tend to use heart rate as the dependent measure. Equivocal findings were also reported in such investigations. Copeland and Franks (1991) investigated participants' reactions to asynchronous music of differing rhythms and intensities ("soft/slow" and "loud/upbeat") on a treadmill endurance task. They recorded HR at 30 s intervals up until voluntary exhaustion and found that HR was significantly lower ($p < .10$) during exposure to "soft/slow" music than control. Thus, they concluded that these findings supported their hypothesis pertaining to the arousal reduction properties of slow rhythmic music of a low intensity during submaximal exercise, leading to increased persistence at the task. However, their results should be interpreted with a degree of caution as the statistical analysis might have been carried out inappropriately. Heart rate data were analysed using a series of one-way repeated measures ANOVAs using each time point. Moreover, the level of significance applied by Copeland and Franks to the heart rate data was above the norm of $p < .05$. These factors may have increased the likelihood of a Type I error.

Two experiments by Dorney et al. (1992) showed that HR can be manipulated by listening to music. In the first study, individuals were made to listen to either slow classical music, fast modern music, or silence on three separate occasions preceding a dart throwing performance. Results indicate that music listening significantly decreased HR regardless of tempo and genre. In the next study, participants assigned to an imagery-plus-music intervention recorded elevated HRs compared to an imagery-only intervention prior to a sit-up task. The authors proposed that music may strengthen the impact of imagery, and consequently, benefit pre-performance strategies. However, they gave no indication as to how exactly an increase in HR might enhance imagery.

Despite the equivocal findings reported for the ergogenic, psychophysical, and psychophysiological effects of music, the evidence pertaining to affective responses during exercise appears to be more encouraging. Boutcher and Trenske (1990) reported more positive affective valence when music was provided compared to both a control and sensory-deprived condition (visual and audio deprivation) at moderate and high workloads. Similarly, Elliot et al. (2005) reported higher in-task affective valence for music conditions in comparison to a control condition, and these elevated levels were still evident post-exercise and 24 hours later. This indicated that music could potentially have a residual effect on the valence component of affective responses after the cessation of music and exercise. Further support was observed by Tenenbaum et al. (2004); results from a hill running task indicated that although RPE was identical between conditions of music and no-music control, participants reported that music enabled them to perceive fatigue symptoms more positively. In a departure from extant theory (Rejeski, 1985), it seems that although music is unable to exert its distractive effects at high exercise intensities, it could still positively influence how an individual interprets the sensations of fatigue (Karageorghis, 2008; Karageorghis & Priest, 2011a; Terry & Karageorghis, 2006).

2.3.3 Early Methodological Issues

A review by Karageorghis and Terry (1997) highlighted that the inconsistent findings observed in previous works were due mainly to methodological limitations and the lack of an underpinning conceptual framework to guide research. One major issue was that no consideration was made for the type of music to be used. In addition, the music selection and the manner in which it was being used were frequently not specified. As a consequence, it was difficult to evaluate the findings and their practical applications. Further, the volume of music was not specified; this could confound results based on the potential for music intensity to impact reactivity to music (Edworthy & Waring, 2006).

Another limitation raised in the review was the lack of emphasis on sociocultural influences, which have been shown to play a role in determining psychophysical responses to music (Hohler, 1989; Lucaccini & Kreit, 1972; see Section 2.2.5.2). For example, social class, area of residence, ethnic background, and peer group influence need to be taken into account when selecting an experimental sample. In addition, age and musical preferences would also need to be considered when selecting the music to be used. Other limitations cited were the failure to account for the duration and point at which music was played in relation to the task (Dorney & Goh, 1992; Pearce, 1981), confusion in music terminology (Copeland & Franks, 1991), selection of inappropriate dependent variables (Lee, 1989, as cited in Karageorghis & Terry, 1997, p. 60), and the use of tasks that are difficult to standardise (Patton 1991, as cited in Karageorghis & Terry, 1997, p. 60).

2.3.4 Conceptual Development

A conceptual framework underpinning the study of the effects of music was developed by Karageorghis et al. (1999; Figure 2.2). They proposed that four factors - rhythm response, musicality, cultural impact, and association - interact to bring out the motivational qualities of music. Rhythm response refers to the natural predisposition of humans to respond to musical rhythm, especially tempo, because it replicates natural forms of physical activity such as walking and running (Hohler, 1989). Musicality refers to the pitch-related aspects of melody and harmony. Cultural impact of music is the pervasiveness of the music within society or a sub-cultural group. Finally, association relates to the attachment of certain thoughts and feelings, to a particular musical composition. An example would be the association of Olympic glory to the composition, *Chariots Of Fire* (Karageorghis & Terry, 2009). The four factors mentioned were proposed to affect a listener's reactivity to music in a hierarchical manner, with rhythm response being the most important aspect, followed by musicality, cultural impact, and of least importance, association (Karageorghis et al., 1999).

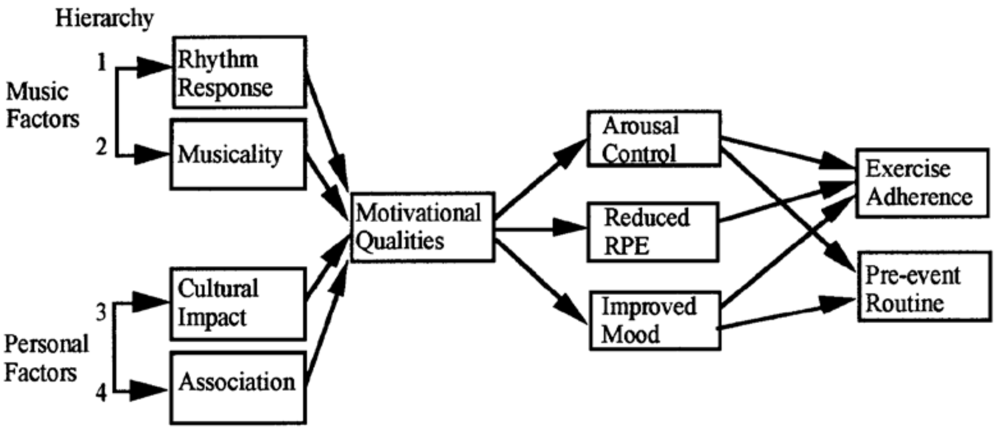

Figure 2.2. Conceptual framework for the prediction of responses to music in exercise and sport (reproduced from Karageorghis et al., 1999).

The conceptual framework was subsequently remodelled and updated, with a greater emphasis placed on the sport context (Terry & Karageorghis, 2006; Figure 2.3). The reworked model posits several benefits that an athlete or exercise participant might receive from music listening: (a) improvement in mood states, (b) arousal regulation, (c) dissociation from internal somatosensory cues such as pain and fatigue, (d) alteration of perceived effort, (e) elevated work output resulting from synchronisation of movement to musical tempo, (f) facilitation of learning and acquisition of motor skills as a consequence of matching rhythm or association with specific movement patterns, (g) enhanced probability of flow state attainment, and (h) increased performance resulting from a combination of any of the above mechanisms.

A criticism that may be levelled at the conceptual model is that, although the mechanisms and outcomes are defined, it reveals little about the processes involved that elucidate the end product (e.g., how do rhythm response or musicality engender an increase in work output?). An understanding of how the brain interprets music and its subsequent effects on the body would enable research in the area to develop further. Nonetheless, Terry and Karageorghis's model has provided a conceptual framework for researchers and considerably advanced both the quality and quantity of research within the area.

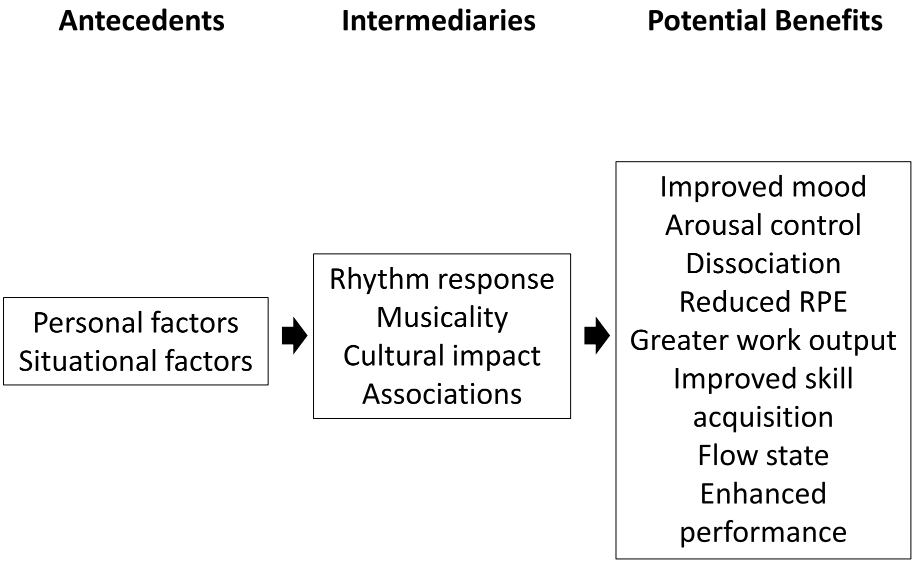

Figure 2.3. Conceptual framework for the impact of music listening in sport and exercise (reproduced from Terry & Karageorghis, 2006).

2.3.5 Alternate Models

The lack of research investigating the application of music in sport from a qualitative perspective prompted Bishop, Karageorghis, and Loizou (2007) to conduct a study employing grounded theory: They investigated how young tennis players' made use of music to regulate their emotional status. Participants' data were collected via a combination of quantitative (music questionnaires) and qualitative (interviews, two-week diary, and observation of facial expressions) methods. Findings revealed that music was deliberately used by participants to invoke certain emotional responses, such as pleasure and self-confidence. These responses overlap some of the benefits proposed by Terry and Karageorghis (2006), thus providing some support for their revised conceptual framework.

A key tenet of Karageorghis et al.’s (1999) earlier model was the hierarchal influence of rhythm response, musicality, cultural impact, and lastly, association, on responses to music. However, in their re-worked model, Terry and Karageorghis (2006) made no mention of whether the hierarchal order of the factors were preserved, which would lead readers to assume that that was indeed the case. Nonetheless, Bishop et al. (2007) observed that the external factors of association and cultural influences were deemed more important than the internal factors in the manipulation of emotional responses. A possible explanation for this contradiction might lie in the context which music is applied to; external factors may be more pivotal at the preparatory stage (i.e., pre-event; cognition/appraisal systems), whereas internal factors might be more salient during the course of an activity.

2.3.6 Motivational Quotient of Music

To investigate music’s motivational qualities in future research, Karageorghis et al. (1999) developed the Brunel Music Rating Inventory (BMRI). The BMRI possesses acceptable validity and reliability (Karageorghis et al., 1999), and a number of studies that have used the BMRI in the selection of music have produced encouraging results, such as improved affective states (Elliot, Carr, & Savage, 2004; Elliot et al., 2005) and reduced ratings of perceived exertion (Karageorghis & Jones, 2000). It has also been found to induce pre-task and in-task flow states (Karageorghis & Deeth, 2002). Nevertheless, even though the BMRI was deemed an acceptable tool for assessing the motivational qualities of music, several limitations were acknowledged by its authors. Firstly, the BMRI was validated using aerobics instructors, who were deemed to be experts in music selection. Accordingly the validation process was based on the instructors' perceptions of what they deemed would motivate exercisers, and did not reflect the actual views of exercise participants. Second, instability in the rhythm response factor was observed in a multi-sample confirmatory factor analysis, while low internal consistency scores were found for items in the cultural impact factor. Lastly, weak relationships were observed between certain items and the factors they were intended to load onto. As a result, the BMRI has been revised and redesigned to account for these limitations (Karageorghis, Priest, Terry, Chatzisarantis, & Lane, 2006). The resultant BMRI-2 has stronger psychometric properties in comparison to the original version, is easier to administer, and has been shown to possess stronger psychometrics properties than its predecessor. The authors of the BMRI-2 suggested that its use in future studies investigating the effects of music might produce more consistent findings, and this has since been proven by the quality of studies that have utilised the BMRI-2 (Crust & Clough, 2006; Hutchinson et al., 2010; Karageorghis et al., 2009; Simpson & Karageorghis, 2006).

2.3.7 Applications of Music

Research within sport and exercise has traditionally utilised music in three ways: Pre-task, in-task asynchronously, and in-task synchronously. Pre-task pertains to the use of a musical stimulus to arouse, relax, or regulate the affective states of an individual or group prior to commencement of activity.

Asynchronous usage is described as the playing of music in the background of the environment during the activity while there is no conscious attempt by the individual to synchronise their movements to the rhythmic qualities of the music (Karageorghis, 2008), while synchronous music involves individuals explicitly matching their movement patterns temporally to the beat or rhythm of the musical stimulus.

2.3.7.1 Pre-task application. A handful of researchers have investigated the use of music as a pre-task stimulant or sedative. Pearce (1981) examined the effects of different types of music on physical strength. She sought to determine whether music of differing arousal potential (i.e., stimulative music, sedative music, silence) would have differential effects on arousal as measured by grip strength. Initial measures of grip strength were recorded for each participant. Following a 30 s pause, participants were then exposed to two min of either music stimulation or silence, depending on the randomised order each participant was assigned to. After another 2 min, grip strength was measured again. This procedure was repeated until each participant had completed all the stimulus conditions. Results indicated a main effect for types of stimulation; sedative music reduced grip strength in comparison to stimulative music and silence, and exposure to stimulative music did not increase grip strength relative to silence.

Karageorghis and his colleagues (1996) criticised Pearce’s study on three counts. Reasons for the specific music selections were not specified; no indication of music intensity was provided, thus it was not possible to determine if volume was standardised across conditions; and experimental tests were conducted in close succession, thus raising the possibility of carry-over effects. Nonetheless, it can be argued that the criticism of experimental conditions conducted one directly after the other is negligible as the order of conditions was counter-balanced, thereby mitigating against possible carry-over effects.

Taking into account these reservations, Karageorghis et al. (1996) replicated Pearce's study, seeking to ascertain the impact of fast, energising music and slow, relaxing music on grip strength performance. Careful consideration was given to the choice of tracks and the sound intensity was standardised. Further, participants were tested once a week over three successive weeks. Findings indicated that listening to uplifting music of a fast tempo resulted in significantly higher grip strength scores compared to slow, sedative music or a white noise control. In addition, participants recorded lower scores when they were exposed to sedative music as opposed to a white noise control. Thus, results lend support to the arousing properties of music. It appears that performance can be enhanced by elevating arousal levels, at least for simple motoric tasks. However, it was unclear whether arousal was indeed responsible for the observed responses as there was no documentation of arousal levels. It is entirely plausible that the increases and decreases in grip strength observed from exposure to stimulative and sedative music respectively were due to cognitive factors (e.g., motivation), rather than variations in physiological arousal.

The investigation of the effects of pre-task music has not been confined to simple, motoric tasks. Ferguson et al. (1994) observed that karatekas' performance on a pre-selected karate drill was significantly enhanced when they listened to either positive or negative music compared to white noise, whilst no differences were observed between music conditions. Subjective evaluations indicated that the music had a comforting and relaxing effect. Several flaws were evident in this particular study: The use of the terms “positive” and “negative” music were not adequately explained by the authors, merely stating that tracks with a quick tempo and high intensity were classed as positive and slow tempo, low intensity songs were rated as negative, with no explanation provided as to what positive and negative music meant. Further, the classification of positive and negative music was flawed; the constituents of tempo and intensity alone are insufficient in judging whether a piece of music is positive or negative. In addition, the tracks used were not stated, rendering it impossible for readers to ascertain whether the tracks used were correctly classified. Nonetheless, results suggest that the use of music, regardless of tempo and intensity, improved performance of a karate drill over a white noise condition.

Eliakim, Meckel, Nemet, and Eliakim (2006) used a more sport-specific sample to determine the effects of pre-task music on anaerobic performance. Twenty four elite-level adolescent players completed the Wingate Anaerobic Test having undertaken a 10-min warm-up while exposed to either a music condition or a no-music control. Mean heart rate was significantly elevated when warming-up to music, and players also recorded higher peak anaerobic power in the Wingate Anaerobic Test. Nevertheless, music did not make any significant difference to the mean anaerobic output or fatigue index. They rightly concluded that even though listening to arousing music during warm-up increases peak anaerobic power, it is unclear whether this translates to better overall performance. On the basis of their findings, it seems unlikely that the intervention influenced overall performance; mean anaerobic power across both conditions was roughly at the same level, and could therefore imply that music simply increased the variability in performance. Similarly, Yamamoto et al. (2003) demonstrated that listening to fast- or slow-rhythm music did not have any influence on mean power output on a supramaximal cycling performance. Interestingly, they reported changes in plasma epinephrine concentrations and norepinephrine of participants when they listened to fast and slow music respectively; both hormones are implicated as potential physiological indicators of arousal (Frey, McCubbin, Dunn, & Mazzeo, 1997; Möckel et al., 1994).

There are three possibilities for the aforementioned findings. First, that music had no effect on supramaximal activities; however, it is premature to suggest that this was the case, considering the haphazard music selection process in these studies. For example, Yamamoto et al. (2003) used music from American cinematic films such as *Rocky* and *Top Gun* in their fast rhythm condition. Given the participants were Japanese, these tracks might be deemed inappropriate due to cultural inappropriateness (Karageorghis & Terry, 1997; Lucaccini & Kreit, 1972), and could, therefore obscure any potential influence of music. Second, there might be a threshold level of arousal to surpass in order to observe changes in performance. Elevated heart rate and epinephrine concentrations are indicative of changes in physiological arousal, but the level of increase may have been insufficient to elicit a concomitant influence on performance. Third, it is plausible that factors other than physiological arousal, such as valence and cognitive arousal, mediated the effects of pre-task music on supramaximal performance. It has been proposed that the use of music in sport is based on the presumption that its emotive and arousing qualities will improve performance (Dorney & Goh, 1992); both Eliakim et al. (2006) and Yamamoto et al. made their musical choices based solely on music's potential to arouse and did not consider the emotive content. The aforementioned possibilities are not mutually exclusive: Selecting music which has cultural significance to participants would invariably contain emotive qualities relevant to the listener.

2.3.7.2 Asynchronous music – in-task application. Most of the research that investigated the effects of music in sport/exercise tends to employ musical stimuli in an asynchronous manner. Karageorghis et al. (1999) proposed that rhythm response, in particular tempo, is the strongest determinant of an individual's response to music. In addition, it has been postulated that an individual's preference for a certain range of tempo may be based on an interaction between his/her physiological arousal and the musical context (North & Hargreaves, 1997).

Iwanaga conducted a series of experiments requiring participants to self-regulate two separate auditory stimuli (i.e., pure tone and music). Findings led him to propose that heart rate and music tempo preference are involved in a positive and linear relationship (Iwanaga 1995a; 1995b). Nonetheless, this proposition was challenged by LeBlanc, who questioned the self-regulatory protocols on the grounds of external validity; he argued that in reality, it was seldom possible for individuals to self-regulate the beat of a musical stimulus and judgements of tempo preference were often made post hoc.

In order to validate Iwanaga's hypothesis and LeBlanc's reservation, Karageorghis, Jones, and Low (2006) asked participants to report preferences for slow (80 bpm), medium (120 bpm) and fast (140 bpm) tempo music excerpts whilst running at different intensities (40%, 60%, and 75% maximal heart rate reserve [maxHRR]) on a treadmill. A significant intensity-by-tempo interaction was observed; fast or medium tempo tracks were preferred for low and moderate exercise intensities whilst fast tempo music was chosen during high intensity exercise. In addition, a significant music tempo main effect was observed, wherein participants preferred fast and medium tempo music to slow music at all intensities.

Extending the research, Karageorghis, Jones, and Stuart (2009) exposed participants to entire music programmes rather than 90 s music excerpts, which were used in their previous study. They also included a mixed tempi music condition, based on the premise that continuous exposure to fast-tempo music during exercise might elicit negative psychological consequences such as boredom and irritation (Karageorghis et al., 2006). Thus, they hypothesised that participants would prefer and derive the most psychological benefits from the mixed tempi intervention. Participants underwent four trials – fast tempi, medium tempi, mixed tempi, and a no-music control – working at 70% of maxHRR in each occasion. Findings served to refute the research hypothesis: Medium tempi yielded the most positive outcomes in terms of music preference, intrinsic motivation, and global flow. Karageorghis et al. (2009) proposed that this observation could be due to the exercise intensity; they reasoned that the workload of 70% was still within the preference range of medium tempi and that an exercise intensity of 75% might have elicited preferences for fast tempi music, as evidenced by their preceding study (Karageorghis et al., 2006). The 75% maxHRR workload was purported to be the point at which the body switches from using a predominantly aerobic energy pathway to a heavy reliance on anaerobic energy processes, whereby internal physiological cues become more salient to the exerciser (Rejeski, 1985, Szabo, Small, & Leigh, 1999). Nonetheless, researchers have observed that at a fixed exercise intensity of 70% aerobic capacity, different ventilatory or lactate threshold levels are exhibited by different people, and therefore might not serve to provide a true standardisation of exercise intensity (Katch, Weltman, Sady, & Freedson, 1978).

The inconsistent observations led Karageorghis and Terry (2009) to suggest that the relationship between music tempo preference and heart rate might be of a quartic nature, with three distinct inflections. Karageorghis et al. (2011) subsequently tested this hypothesis, which revealed some interesting findings; although a quartic relationship between music tempo preference and heart rate was significant, a cubic relationship was also evident. In fact, a graphical representation of both variables ostensibly depicts a cubic relationship. Specifically, a linear increase in preferred music tempo was observed at low to moderate exercise intensities, followed by a plateau at moderate to high exercise intensities, and a slight decline at very high exercise intensities (80% HRRmax).

Research on the asynchronous application of music under laboratory settings has yielded several positive results. Elliot et al. (2004) required participants to cycle at an intensity that corresponded to a particular RPE score for 12 min under three conditions: Motivational music, oudeterous music, and a no-music control. They reported an increase in participants' work output and positive affect when administered with motivational or oudeterous music as opposed to no music. Furthering this line of investigation, Elliot and his colleagues (2005) examined the effects of motivational music using a 20 min submaximal cycling task. Similar to the preceding study, participants were able to achieve higher workloads and more positive affective states regardless of the motivational qualities of the music. Further, positive attitudes towards exercising with music were evident post-trial and 24 hours later, suggesting effects remain even after cessation of music accompaniment. Taken collectively, these experiments support early research concerning the influence of music on affective responses during exercise, even at high intensities (Boutcher & Trenske, 1990).

Psychophysiological responses have also been well documented within the literature. Copeland and Franks (1991) reported that soft, slow music lowered heart rate compared to loud, fast music and a no-music control at different time points during a treadmill task to voluntary exhaustion. Further, time to exhaustion was significantly longer in the soft, slow music condition compared to no music. They proposed that soft, slow music had a calming effect on participants that improved their cardiorespiratory endurance, although no mechanisms were advanced to explain this proposition. In addition, it was previously highlighted that the choice of statistical analysis may have inflated the possibility of a Type I error. A more appropriate statistical test would have been a two-way repeated measures ANOVA, set at a significance confidence of 95% instead of 90% which would have facilitated a overall comparison of mean heart rate across conditions while reducing the likelihood of a Type I error occurring.

Investigating a wider range of physiological variables, Szmedra and Bacharach (1998) demonstrated decreased heart rate, systolic blood pressure, lactate concentration, and norepinephrine secretion when participants ran at 70% $\dot{V}O_{2max}$ with background music. They speculated that listening to the music gave participants a sense of tranquillity that helped alleviate muscular tension, and consequently improved blood flow and lactate removal whilst inhibiting lactate production in exercising muscles. Given the nature of their findings, it is entirely plausible that listening to music during exercise may have a relaxing effect on muscle activity.

More recently, researchers have reported cardiovascular changes during steady-state exercise in response to fast music exposure relative to slow music and no music (Birnbaum, Boone, & Huschle, 2009). Birnbaum et al. observed significant elevations in stroke volume (SV) and cardiac output (Q), which led to an increase in oxygen consumption ($\dot{V}O_2$) when participants listened to fast music. Interestingly, neither music condition had any effect on heart rate or blood pressure, an indication that myocardial oxygen consumption ($M\dot{V}O_2$) was similar. Birnbaum et al. concluded that listening to fast music during steady-state exercise had a somewhat contrasting impact; it decreased cardiovascular efficiency but at the same time enabled individuals to burn more calories without an additional burden to $M\dot{V}O_2$. However, it might be argued that the exercise protocol did not allow an accurate assessment of workload. Participants were required to run at a treadmill speed of 5.5 mph for 15 min. Even though the treadmill speed was standardised, it was possible to run at a pace faster than the pre-ordained velocity. Accordingly, the findings might not necessarily indicate cardiovascular inefficiency but rather an increased capacity to do work without additional strain to the heart. Further, the exercise intensity was set in relation to one participant’s maximum heart rate. This is a severe methodological flaw, as it is highly unlikely that all 11 participants in the study had the same maximum heart rate. A more precise indication of one’s physiological status would have been to standardise exercise intensities using more individualised protocols (e.g., $\dot{V}O_{2max}$, ventilatory threshold [T_{vent}], HR). The use of some form of performance measure such as stride rate and length would also have led to a clearer understanding of this phenomenon.

Perceptions of effort seem to be heavily influenced by music. Szmedra and Bacharach (1998) found that participants reported a 10% reduction in RPE when running at 70% $\dot{V}O_{2max}$ with background music. A similar percentage reduction was obtained by Nethery (2002); participants listening to music reported significantly lower RPE compared to a video, sensory-deprived, and no-music control condition during a 15-min cycling task at both low (50% $\dot{V}O_{2peak}$) and high workloads (80% $\dot{V}O_{2peak}$). Using differing exercise loads; 60% (light), 75% (moderate), and 85% (heavy) of maximal heart rate, under three conditions (i.e., music, sensory deprivation, and control), Boutcher and Trenske (1990) found that music significantly lowered participants’ RPE only at low workloads. There was no difference at moderate and heavy exercise intensities compared to deprivation and control. These findings partially concur with Rejeski's parallel processing model (1985), that the influence of external distractive stimuli has the greatest impact at submaximal intensities on perception. As workload progressively increases, internal physiological cues tend to occupy attentional focus, resulting in increased awareness of exertion.

Tenenbaum et al. (2004) observed that music did not influence perceived effort in either a laboratory-based or outdoor running task at 90% $\dot{V}O_{2max}$. Nonetheless, participants reported preference for music, stating it was enjoyable, motivating, and distracted them from the task. At supramaximal exercise levels, music seems to be ineffectual; Pujol and Langenfeld (1999) reported that music was inconsequential on Wingate performance. However, it is unclear whether music would have had an influence on affect as this variable was not measured by the researchers. Consistent with the load-dependent hypothesis, research has shown that the benefits of asynchronous music with regards to performance, RPE, and other psychophysiological variables, diminish with increasing exercise intensities (Anshel & Marisi, 1978). Nevertheless, it has been demonstrated that the effects of music on affective states are not subjected to the predictions of the load-dependent hypothesis (Boutcher & Trenske, 1990; Tenenbaum et al.).

2.3.7.3 Differentiated asynchronous music exposure. An area within asynchronous music research that has received scant attention is the manipulation of music exposure in a task. This form of music manipulation has been examined mostly in vigilance tasks (see Lucaccini & Kreit, 1972, for a review). Lucaccini (1968) reported that participants presented with music separated by short breaks (5-15 s) fared significantly better in visual stimulus detection tasks when compared to white noise exposure. Similar performance benefits were also found by Davenport (1974), whose participants had to detect deviations in the amplitude of a static sine wave pattern for a duration of 160 min. Four types of musical accompaniment, lasting 40 min each, were presented in the background to participants:Fixed interval music (20 s silence interpersed with 20 s music), continuous music, variable interval music (15s to 25 s silence), and random interval music (silence and music ordered randomly). Participants' detection rates were higher in the variable and random interval music conditions when compared to fixed interval and continuous music conditions. Both sets of results were interpreted using arousal theory; the unpredictability of the music stimulus elevated arousal levels that otherwise would have dipped as a consequence of task monotony.

Adopting a similar view, Lim et al. (2009) tested the concept of differentiated music exposure in a sport and exercise context. They had participants complete a 10-km time trial under three music conditions: No-music control, music 0-5 km, and music 5-10 km. Although no significant performance benefits were observed, the trend was in the right direction; participants cycling in the music 5-10 km condition registered shorter race times. A number of limitations were raised by Lim et al., but their results indicate that there is the potential for differentiated music exposure application in sport and exercise tasks.

2.3.7.4 Synchronous music. Interest in the relationship between musical rhythm and motor behaviour started as early as the beginning of the

20th century; music was suggested to be a stimulus that encourages “natural movement” (MacDougal, 1902). In addition, it has also been proposed that humans have a natural predisposition to move to the beat or rhythm of music (Wilson & Davey, 2002). Thus, it would seem that music and movement are closely related to each other. In addition, researchers have demonstrated the close relationship between musical and certain physiological rhythms (Bernardi, Porta, Casucci...et al., 2009), thus providing further indication of the similarities shared between music and certain innate human rhythms.

The idea of moving in synchrony with music is not a recent development aerobics and spin cycling class instructors have been promoting such a concept for years. In the sporting domain, there are several pursuits in which music is an important component: Figure skating, rhythmic gymnastics and synchronised swimming to name but a few. Haile Gebreselassie, world-renowned long-distance runner, has often been cited as an example to illustrate the effects of synchronising movement to music; he broke the indoor world record for 2000 m in February 1998 while apparently synchronising his stride rate to the pop song, *Scatman*. Despite the fact that movement-to-music synchronisation occurs often in the real world, little scientific research into the link between movement and music has been conducted.

The few studies that have been carried out nonetheless suggest that synchronising movement to the rhythm or tempo of music engenders significant benefits. Positive findings have been reported in bench stepping (Hayakawa et al., 2000), cycle ergometry (Anshel & Marisi, 1978; Bacon et al., 2012; Mertesdorf, 1994), callisthenic-type exercises (Uppal & Datta, 1990), an exercise circuit task (Michel & Wanner, 1973), treadmill walking (Karageorghis et al., 2009), and on a 400 m sprint performance task (Simpson & Karageorghis, 2006).

One of the earliest studies in this area was conducted by Anshel and Marisi (1978), who examined the effects of synchronous and asynchronous music on physical endurance during a cycle ergometer task. Sixteen male and 16 female undergraduate students were required to cycle under three conditions: (a) moving in synchrony to the musical stimulus; (b) asynchronous music with a visual pacing stimulus; and (c) no music with a visual pacing stimulus. Participants endured the physical task significantly longer when cycling to synchronous music compared to asynchronous music or no music ($p < .001$). However, a possible limitation was the arbitrary nature in which the music was chosen: No consideration was given to the musical preferences and socio-cultural upbringing of participants, factors which have been proposed to influence individual responses to music (Lucaccini & Kreit, 1972; Karageorghis & Terry, 1997; Karageorghis et al., 1999). Nonetheless, given that positive results were still observed with the arbitrarily selected music, the careful consideration of participants' musical preferences in future studies might elicit stronger responses.

Hayakawa et al. (2000) investigated the influence of synchronous music (aerobic dance), asynchronous music (traditional Japanese folk), and a no-music control on mood during a step aerobics class. More positive moods were reported following exposure to synchronous music compared to the other two conditions. However, Karageorghis (2008) suggested that it was uncertain whether the improved mood was due to the music itself or the physiological demands of the exercise class. He further commented that it was unclear to what extent the results could be attributed to the music genre (i.e., dance versus folk) or to movement-to-music synchronicity. Given that participants were exposed to two other conditions comprising asynchronous music and no music; it could be assumed that the improved mood was most likely a result of music exposure. The second issue is more contentious, and could possibly be circumvented in future research by using tracks with similar musical styles or even the same track played at different tempi.

More recently, Karageorghis et al. (2009) investigated the impact of motivational and oudeterous synchronous music in apposition to a no music control on walking to volitional exhaustion at 75% maximal heart rate. Four dependent variables were examined: Time to exhaustion, RPE, in-task affective valence, and exercise-induced feeling states. They observed that time to exhaustion was significantly increased in the music conditions compared to control, and endurance was 6% higher for motivational music in comparison to oudeterous music. Main effects were also reported for in-task affective valence; motivational music elicited more positive affective responses than the no-music control. No significant interactions were reported for any of the dependent measures, while no significant main effects were observed for RPE, HR, and exercise-induced feeling states. Findings indicated that synchronising walking to a musical stimulus resulted in a greater endurance at the task, and this effect was magnified when the motivational characteristics of the music are considered In addition, motivational synchronous music elicited higher in-task affective valence compared to the control condition throughout the endurance task. This particular finding lends further credence to the proposition that the impact of music on affective states is not load dependent (Boutcher & Trenske, 1990; Elliot et al, 2005; Tenenbaum et al., 2004), as previously claimed (Rejeski, 1985, Tenenbaum, 2001).

It has been suggested that the ergogenic effects associated with synchronous music use are a consequence of greater neuromuscular or metabolic efficiency (Terry & Karageorghis, 2006). A few studies have shown physiological changes under asynchronous music situations: Reduced heart rate at fixed sub-maximal intensities (Copeland & Franks, 1991; Szmedra & Bacharach, 1998), decreased lactate concentration and exercise blood pressure (Szmedra & Bacharach), and increased workload in a progressive cycling to voluntary exhaustion task without concomitant increases in heart rate (Szabo et al., 1999). Nonetheless, these physiological parameters are just an indirect indication that efficiency might be a possible mechanism that yields ergogenic effects. The assessment of direct and objective measures of neuromuscular or metabolic efficiency such as electromyographic data or oxygen consumption ($\dot{V}O_2$) respectively, would provide concrete evidence to enable researchers to test this proposition.

In an attempt to directly examine this relationship between music synchrony and efficiency, Bacon, Myers, and Karageorghis (2012) had their participants cycle for 12 min at a workload equivalent to 70% maximal heart rate while listening to music at different tempi. Participants were required to maintain a pedal cadence of 65 rpm under three music conditions; synchronous (130 bpm), fast asynchronous (137 bpm), and slow asynchronous (123 bpm). The dependent measures were mean $\dot{V}O_2$, heart rate, and RPE. They observed that mean $\dot{V}O_2$ differed across conditions; it was lower with synchronous music compared to slow asynchronous music. No significant effects were reported for heart rate or RPE. Taken together, these findings do lend support to the notion that moving in time with music improves metabolic efficiency. However, results should be treated with a degree of caution; the lack of a no-music control trial that entailed participants just cycling at the prescribed cadence meant that Bacon et al.'s findings do not actually indicate improved efficiency with music, but merely that synchronous music makes movement more efficient in comparison to slow asynchronous music. It is unclear if these findings are superior to merely maintaining cadence without music. Nonetheless, apart from the omission of a control condition, this was a very well designed experiment and certainly warrants further investigation.

The aforementioned research employed either time to exhaustion or sub-maximal exercise intensity protocols, ignoring the potential effects synchronous music might have on anaerobic tasks. It might be argued that considering the ineffectiveness of asynchronous music on anaerobic type activities (Pujol & Langenfeld, 1999; Tenenbaum et al., 2004), applying synchronous music at high exercise intensities would yield similar results. Nonetheless, Simpson and Karageorghis (2006) attempted to test this notion by exploring the effects of synchronous music during 400-m sprint performance. They found that both the application of motivational and oudeterous synchronous music led participants to achieve faster times in comparison to a no-music control, and that both experimental trials were similar. Two conclusions were drawn: The influence of synchronous music is not constrained by load; and at high exercise intensities, the motivational qualities of music were considered insignificant. It would thus be worthwhile for future researchers to investigate the impact of synchronous music on affective responses during anaerobic tasks.

2.4 Relationship between Central Governor Model, RPE, and Pacing Strategies

Noakes and colleagues (Noakes, St Clair Gibson, & Lambert, 2005) forwarded the *Central Governor Model of Fatigue* (CGM) as an alternate theory to explain the limits of exercise performance and fatigue. This model was predicated on Ulmer’s notion of teleoanticipation (1968). Contrary to research that suggested performance regulation happens peripherally at the muscles (Edwards, 1983, as cited in Noakes et al., 2005, p. 120), Noakes et al. contended that this regulation is governed by the central nervous system. The CGM posits that the human body operates as a complicated system during exercise, with the brain as the main regulatory centre of this system. Physiological, biochemical, and other sensory outputs from the periphery are integrated and processed centrally, and if necessary, work output is moderated to prevent homeostatic disruptions in the body.

Noakes et al. (2005) also contested that traditional models of fatigue cannot explain an important component of sport and exercise, “which is the rapid adoption, shortly after the onset, of different pacing strategies during exercise of very different intensities and durations.” (p. 122). The CGM, however, appears to be able to account for these rapid and constant changes. According to the model, the subconscious brain sets the exercise intensity by determining the number of motor units that need to be activated and hence the mass of skeletal motor units to be recruited that are required to complete a sport or exercise task. More importantly, utilising feed forward control and in response to multiple feedback sensors, both centrally and peripherally, the brain is able to rapidly alter the pacing strategy accordingly such that an activity, e.g. 10-km cycling time trial, can be completed without any compromise to cellular homeostasis. Control is applied by moderating skeletal muscle recruitment during exercise and by the inhibitory effects of the increasingly disagreeable sensations of fatigue that are generated by the brain during exercise. Ratings of perceived exertion have been suggested as the fatigue sensation, and appear to be important in the regulation of exercise performance (Baden, McLean, Tucker, Noakes, & St Clair Gibson, 2005; St Clair Gibson et al., 2006). Indeed, studies have observed that work output is adjusted according to the prevailing environments, but RPE profiles remained consistent (Joseph et al., 2008; Tucker, Rauch, Harley, St Clair Gibson, 2004; Tucker, Marle, Lambert, & Noakes, 2006).

2.5 Rationale for Current Research Programme

The underlying rationale for this thesis is twofold. Firstly, the concept of differentiated music exposure is a relatively new idea, at least in the domain of sport and exercise. Thus Chapter 3 was an attempt to develop this line of research, which had been previously undertaken by Lim et al. (2009). Their results suggested that music introduced for a particular segment has an impact on pacing strategies. Taking into consideration the limitations that they raised, a more robust experimental design was employed in the current study. More specifically, participants were blinded to the experimental conditions in order to maintain internal validity. Further, an additional music condition – music 0-10 km – was included in order to assess if the effects of differentiated music exposure are more positive than simply listening to music for the entire time trial. Music was selected in accordance with the guidelines proposed by Karageorghis et al. (1999).

Extending the research on Chapter 3, Chapter 4 employed qualitative methods of inquiry in addition to quantitative means to better understand the thoughts and responses of participants. More crucially, participants in Chapter 4 were given knowledge of the experimental conditions. This was done for two reasons. Given that Chapter 3 would have established the internal validity of such music applications, it appeared logical to investigate if these findings were transferable to settings that reflect reality; personal music listening in the real world is almost always a conscious decision. Secondly, the provision of information with regards to a changing external environment would allow researchers to investigate the influence of music on pacing strategies. It has been proposed that in self-paced tasks, workload is regulated to maintain a pre-programmed RPE template (St Clair Gibson et al. 2005). One of the much researched effects of music is its ability to reduce perceptions of exertion during exercise at a submaximal intensity. Therefore it would be interesting to examine if such effects are observed in self-paced activities, and if so, how does it fit into current understanding of the relationship between RPE and pacing strategies.

The other rationale for the present research programme stemmed from the lack of investigation on synchronous music use in sport and exercise. Although there are conceptual frameworks detailing the effects of music, these were conceptualised specifically for pre-task and asynchronous applications of music. Accordingly, the underlying mechanisms regarding movement-to-music synchrony in sport and exercise contexts are presently unclear. Moreover, judging from the extant literature, researchers appear to assume that the effects of synchronous music compared to asynchronous music application are different. Logically, this would seem to be the case. But in the last 35 years, only one study has examined these two music applications directly in the same study, and results were inconclusive (i.e., Anshel & Marisi, 1978). Thus, Chapter 5 was conceived to fill this void in the literature, and shed more light onto the underlying differences and potential mechanisms that govern the synchronous application of music.

Chapter 3: Ergogenic, Psychophysical, and Psychological Effects of Single-blinded Differentiated Music Exposure on a 10-km Cycling Time Trial

3.1 Introduction

Researchers investigating the effects of asynchronous music in the domain of sport and exercise have predominantly employed submaximal exercise intensities (e.g., Boutcher & Trenske, 1990; Elliot et al., 2004; 2005), or time-to-exhaustion protocols (e.g., Copeland & Franks, 1991; Crust & Clough, 2006). Such protocols conducted in highly controlled laboratory environments have yielded positive findings, adding substantially to the body of knowledge. Nonetheless, it is plausible that some of the potential benefits associated with musical accompaniment observed in such laboratory-based protocols (e.g., reduced RPE, improved affective states) may not equate to tangible improvements when transferred to a sporting context. Indeed, some researchers have argued that such protocols are not reflective of the reality of sports competitions where work rates are often self-selected (Atkinson, Wilson, & Eubank, 2004; Lim et al., 2009). This argument has strong intuitive appeal, although it is common practice in scientific experimentation to establish a high level of internal validity before attempting to apply findings into real-world situations (Karageorghis & Terry, 2009). It now appears timely and warranted to examine such effects using more externally valid protocols, to see if these benefits are replicable in sport-related tasks.

Karageorghis (2008) recently acknowledged that the time was nigh for research within the area to be extended to situations and environments that more closely reflect reality. A small body of research exists in which more externally valid protocols were used, such as a karate drill (Ferguson et al., 1994), a 10-km cycling time trial (Atkinson et al., 2004; Lim et al., 2009), and a 500 m rowing sprint (Rendi, Szabo, & Szabo, 2008); these all reported beneficial effects of music. Nonetheless, more research using self-paced protocols is necessary to establish whether music has a facilitative effect when used in a more externally valid mode.

3.1.1 Music Manipulation

Research that has examined the effects of asynchronous music as an in-task intervention has traditionally employed a music stimulus throughout the entire duration of the experimental procedure (e.g., Atkinson et al., 2004; Boutcher & Trenske, 1990; Copeland & Franks, 1991; Crust & Clough, 2006; Elliot et al., 2004; Elliot et al., 2005; Tenenbaum et al., 2004). Although authors have investigated the effects of varying musical properties such as tempo (Waterhouse, Hudson, & Edwards, 2010) and volume (Edworthy & Waring, 2006), they did not attempt to manipulate these musical properties during the task, with the exception of Szabo, Small, and Leigh (1999).

Szabo and colleagues (1999) investigated the effects of in vivo music tempo manipulation by switching tempo midway through the exercise task. Participants progressively cycled to voluntary physical exhaustion under five different music conditions: *No-music control*, *slow music*, *fast music*, *slow-to-fast music*, and *fast-to-slow music*. They contended that if a change in arousal exerted a positive impact on exercise performance, fast music and switching from slow to fast music at the onset of higher intensity exercise

(70% of maximal heart rate reserve, maxHRR) would elicit superior performance than slow music.

Szabo et al.’s (1999) findings indicated that switching from slow to fast music resulted in significantly greater workloads being completed without proportional changes in heart rate. They proposed that these effects may be due to temporary dissociation from fatigue at high intensities; a change from slow to fast tempo music as participants approached 70% maxHRR could have resulted in them experiencing a temporary switch from an internal to external focus of attention. Nonetheless, they suggested that as exercise continues and fatigue increases, there was an inevitable switch back to an internal focus because the auditory stimulus would be insufficiently arousing to compete with the heightened internal sensations of fatigue. These suggestions require further validation as RPE and arousal were not assessed in their study, and accordingly, the observed ergogenic effects of music could not be solely attributed to dissociative mechanism (Karageorghis, 2008). Further, Szabo et al. used an exercise protocol that was not considered externally valid (Atkinson et al., 2004); therefore observations might be different in self-paced experimental tasks.

3.1.2 Research Employing Externally Valid Protocols

Atkinson et al. (2004) asked participants to complete two 10-km cycling time trials under two different conditions: With and without music. They reported that overall time to completion was faster when participants had asynchronous music accompaniment compared to cycling without music, and noted that the faster cycling times were due to an increase in speed during the initial 3 km of the time trial. However, RPE scores were higher under the music condition, which served to refute the dissociation hypothesis.

Two possible explanations were advanced by the authors. Firstly, participants might have been subconsciously synchronising their movements to the rhythmical components of the music, even though they were not instructed to do so at any point prior to or during sessions. There is a burgeoning body of evidence (Anshel & Marisi, 1978; Karageorghis et al., 2009; Simpson & Karageorghis, 2006) to suggest synchronising movement to music enhances work output. However, the absence of an outcome variable that could account for the possibility of synchronisation (i.e., cadence-beat matching) renders it difficult to attribute any ergogenic effect solely to auditory-motor synchronisation. The other, more likely, possibility is that the asynchronous music acted as a form of motivational aid, enabling participants to work harder; speed and power output were considerably higher under the influence of music. This consequently led to the observed increase in overall performance.

Given this possibility, there is a likelihood that if music were introduced later in the time trial, then participants would be able to sustain higher speeds during the latter stages. The ergogenic effects of music reported in Atkinson et al.’s (2004) study were observed early in the time trial, where participants were, arguably, unlikely to be experiencing much fatigue and would thus have ample physical and mental resources to generate higher workloads. This is corroborated by the increased speed profile evident during the initial 3 km (see Figure 3.1). It is plausible that the introduction of a musical stimulus at a point where participants were experiencing higher levels of fatigue, the ergogenic, psychophysical and psychological effects might be more pronounced when compared to music introduced from the start. Certainly, the results observed by Szabo et al. (1999) would seem to strongly support the plausibility of such a notion, considering the underlying mechanisms are similar (arousal hypothesis and parallel processing model; Karageorghis & Terry, 1997; Rejeski, 1985). Similar ideas have been researched in other fields, specifically on vigilance tasks (see Lucaccini & Kreit, 1972, for a review). For example, researchers reported that participants presented with music separated by short breaks (5-15 s) fared significantly better in visual stimulus detection tasks when compared to white noise exposure (Lucaccini, 1968).

Taking the aforementioned suggestions into consideration, Lim et al. (2009) investigated the impact of differentiated music exposure during a 10-km cycling time trial. Specifically, there were three conditions in their protocol: No-music control (C), music 0-5 km (M1), and music 5-10 km (M2). They assessed eight dependent variables: Overall time to completion, power output, speed, cadence, RPE, blood lactate, and positive and negative affect.

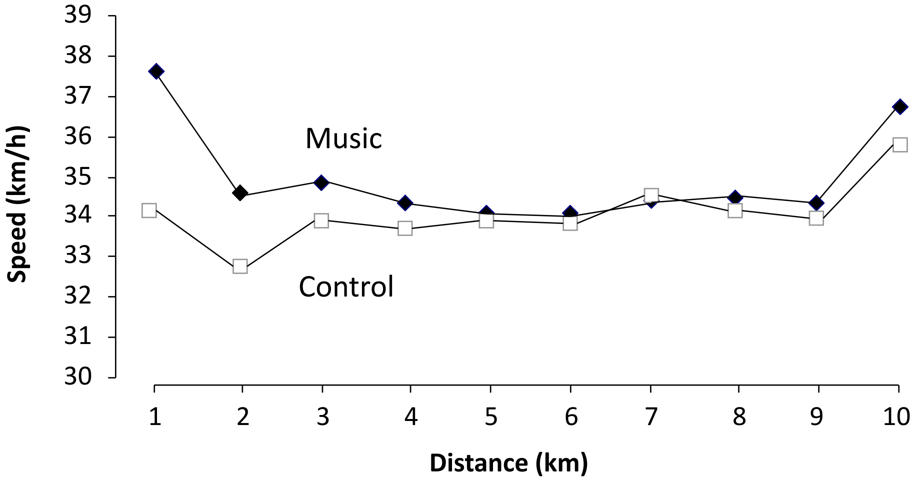

Figure 3.1. Significant Speed x Distance interaction (*p* < .05) for music compared to a no-music control condition. Adapted from “Effects of Music on Work-Rate Distribution during a Cycling Time Trial,” by G. Atkinson, D. Wilson and M. Eubank, 2004, *International Journal of Sports Medicine*, *25*, p. 613. Copyright 2004 by Thieme Publishing Group.

Despite the fact that the expected main effects did not emerge, there was a significant Condition x Distance interaction: Participants recorded higher starting speeds for M2 compared to C and M1. This observation was peculiar as participants were exposed to music only during the latter stages of the M2. Therefore, the mean increase in starting speeds is difficult to explain given that it occurred in the absence of music. In addition, even though participants in M1 were provided with music for the first half of the trial, the speed profile for this condition was almost identical to the no-music control; there were no increases in velocity over the first 5 km. Further, there were no differences in RPE scores across conditions. The arousal hypothesis

(Karageorghis & Terry, 1997) and the parallel processing model (Rejeski, 1985) as mentioned by Szabo et al. (1999) did not seem to adequately explain the interaction.

Lim et al. (2009) proposed the central governor model of fatigue (Noakes et al., 2005) as an alternative explanation. According to the model, the brain sets the appropriate pacing strategy prior to the commencement of the activity; necessary skeletal motor units are recruited to ensure the task is completed without severe homeostatic disruption. Thus, the experimental manipulation may have caused participants to alter their pacing strategies, through neural and behavioural changes. Several limitations were acknowledged by the authors; most notably the weaknesses in the selection of music, a relatively small sample size, and the possible inappropriateness of the measurement scale for affect. As Lim et al.’s study was exploratory in nature, in that it was the first to manipulate music exposure in a self-paced, externally valid exercise protocol. Further work adopting a similar approach is warranted.

3.1.3 Rationale

In the studies conducted by Atkinson et al. (2004) and Lim et al. (2009), participants were given foreknowledge of each experimental condition they were to be exposed to. This action was taken to maintain the external validity of the experiments, as it was argued that in real-life scenarios, individuals would have prior knowledge about when music would be heard. Nonetheless, it is the general norm in empirical research to establish a level of internal validity before moving the research into real world situations. Accordingly, there is a need to investigate the effects of differentiated asynchronous music exposure when participants are blind to the experimental manipulation. Further, several limitations were raised in previous research (i.e., Lim et al.), such as the inappropriate procedures employed for music selection, the need for larger sample sizes, and the use of a more valid measurement tool to assess affective responses. These issues need to be addressed to ensure results were not compromised by any of these factors. In addition, the inclusion of another experimental condition, music 0-10 km, would allow for a more meaningful comparison; it is unclear if the impact of differentiated music exposure is any different compared to when music is presented throughout the task.

3.1.4 Purpose

The purpose of the present study was to investigate the effects of differentiated synchronous music exposure using a single-blinded approach, while employing an externally-valid exercise protocol. Three music conditions were included: *Music 0-10 km (M1)*, *music 0-5 km (M2)*, and *music 5-10 km (M3)*. Based on theory (Karageorghis et al., 1999; Terry & Karageorghis, 2006) and previous findings (Atkinson et al., 2004; Lim et al., 2009), it was hypothesised that: (a) cycling performance would be superior for all music conditions, compared to a no-music control condition; and (b) participants would record faster times when exposed to music for the second half, compared to music in the first half of the task. It is presently unclear whether having music played throughout will elicit superior performance when compared to the other music conditions. Accordingly, the null hypothesis was tested for this particular comparison; (c) ratings of perceived exertion would not be significantly different if participants recorded faster cycling times under music conditions, while similar cycling times would result in a significant reduction in RPE with music accompaniment; and (d) more positive affective valence and higher subjective arousal responses are expected in the conditions where participants are exposed to music.

3.2 Methods

3.2.1 Music Selection

3.2.1.1 Participants. A sample of 147 volunteer students (M_{age} = 19.16 years) from Brunel University and Canterbury Christ Church University were recruited to determine a pool of possible musical selections for use in the experimental protocol of Stage 2. These students matched the profile of the intended sample of experimental participants both in terms of age and sociocultural background: They were Caucasians who have been raised in the United Kingdom, and between 18 and 24 years of age (cf. Karageorghis & Terry, 1997). Written informed consent (Appendix A) was obtained from all participants involved in the music rating process.

3.2.1.2 Procedures. Participants were requested to select five pieces of music that they would prefer to listen to during repetitive exercise such as that conducted on a cycle ergometer or treadmill. The 32 most frequently selected tracks were chosen, and their motivational qualities were subsequently rated by a panel of eight undergraduate sport sciences students from Brunel University using the Brunel Music Rating Inventory-2 (BMRI-2; Karageorghis et al., 2006, Appendix B). This procedure was carried out to ensure that even though the tempi of the tracks differed, there was homogeneity across the other motivational qualities of the music, and so this factor did not present a threat to the internal validity of the present study. In addition, the panel was requested to rate the music with reference to a cycle ergometry task in order to ensure compatibility with the main cycling protocol. The demographics of the rating panel matched the required profile for the pool of experimental participants in terms of age and sociocultural background, as in line with recommendations (Karageorghis et al., 1999). Copyright permission was requested from the relevant music publishers to record the tracks for research purposes.

3.2.1.3 Playlist compilation. A playlist comprising seven tracks was chosen (Appendix C) from the 32 musical selections; they were selected based on their high motivational qualities and appropriate tempo range (130-141 bpm). Previous researchers (Atkinson et al., 2004; Lim et al., 2009) that employed a similar experimental design used musical stimuli exhibiting similar tempi. Thus, this would faciliate meaningful comparison of the present findings with those of past studies. The total duration of the playlist was approximately 30 min, which was deemed sufficient when judging from the race times previously recorded (Atkinson et al.; Lim et al.).

Given that the level of cycling ability and physical fitness of participants varied, some were likely to record faster times than others. Accordingly, these faster individuals would be exposed to fewer tracks than would the slower participants. Thus, the playlist was randomised for every participant, and for each experimental trial, to ensure that participants were exposed to every track in the list to increase the likelihood of participants being exposed to every single track in the list.

3.2.2 Experimental Investigation

3.2.2.1 Power analysis. A power analysis was conducted to establish appropriate sample size with alpha set at .05 and power at .8 to protect beta at four times the level of alpha (Cohen, 1988). A conservative estimate of .5 was selected for the inter-correlation between repeated measures, while the non-sphericity correction was entered as 1. Using an estimated moderate size for the effect of asynchronous music compared to a no-music control (f = 0.25, Atkinson et al., 2004), it was estimated that a total of 24 participants would be required.

3.2.2.2 Participant characteristics. Participants comprised 24 Caucasian males (M_{age} = 20.6 years, M_{weight} = 75.7 kg, M_{height} = 178.1 cm) from the body of Sport Sciences undergraduates at Brunel University. A male-only sample was chosen owing to the possible effects of the menstrual cycle on performance/affective responses (Reilly, Atkinson, & Waterhouse, 1996) that would have made testing impractical; one would have to wait in between trials to test females at a similar stage of their menstrual cycle to yield meaningful findings. There is also the possibility that the internal validity of the study would be compromised; mood states have been found to vary through the course of the menstrual cycle, and by logical extension, the effects of music on affect may be compromised and present a potential confound (Reilly et al.). Further, given that the researcher is male, there could be potential ethical issues with regards to enquiring about a female participant's menstrual cycle; it could be deemed highly inappropriate and insensitive for a male researcher to request for such details.

Participants who completed all sessions were paid £10 as reimbursement for travel. They were briefed on the nature of the study, provided written consent (Appendix A), and filled out a health questionnaire (Appendix D) before commencing the experiment. All procedures employed were approved by Brunel University's Research Ethics Committee.

3.2.2.3 Familiarisation. Participants were required to undergo one familiarisation session; pilot work by Atkinson et al. (2004) indicated that this is necessary to reduce systematic and random errors associated with a 10-km time trial distance. Further, research by Altareki et al. (2006) found that at least one familiarisation trial was required to reduce the possible influence of learning effects with the use of the CompuTrainer ergometer (RacerMate, UK) for a time trial protocol. Although the cycle ergometer used in the current study was the Velotron (RacerMate, UK), the results obtained by Altareki et al. were applicable as the two ergometers are manufactured by the same company and serve almost identical purposes. This session also served to acquaint participants with the different psychological and psychophysical scales that were to be administered during the experimental phase.

3.2.2.4 Experimental design. Participants underwent a total of four experimental trials (see Figure 3.2): Control condition with no music (control); music throughout the trial (M1); music introduced from 0-5 km (M2); and music introduced from 5-10 km (M3). The trials were administered in a counterbalanced order to guard against potential familiarisation/learning effects, and tests were separated by at least 48 hr to enable adequate recovery. Participants were requested to adhere to identical patterns of activity (no other vigorous physical activity) and diet 24 hr prior to the trial, and to refrain from eating 2 hr prior to testing. Each participant engaged in the trial individually in the presence of a same-sex researcher (cf. Anshel & Marisi, 1978). Music intensity was standardised at 85 dBA by use of a decibel meter (AZ 8928; AZ Instrument Corporation, Taichung City, Taiwan); this level is within safe limits from an audiological perspective (see Alessio & Hutchinson, 1991). The playlist was stored in a computer laptop and delivered via speakers located at the rear of the laboratory.

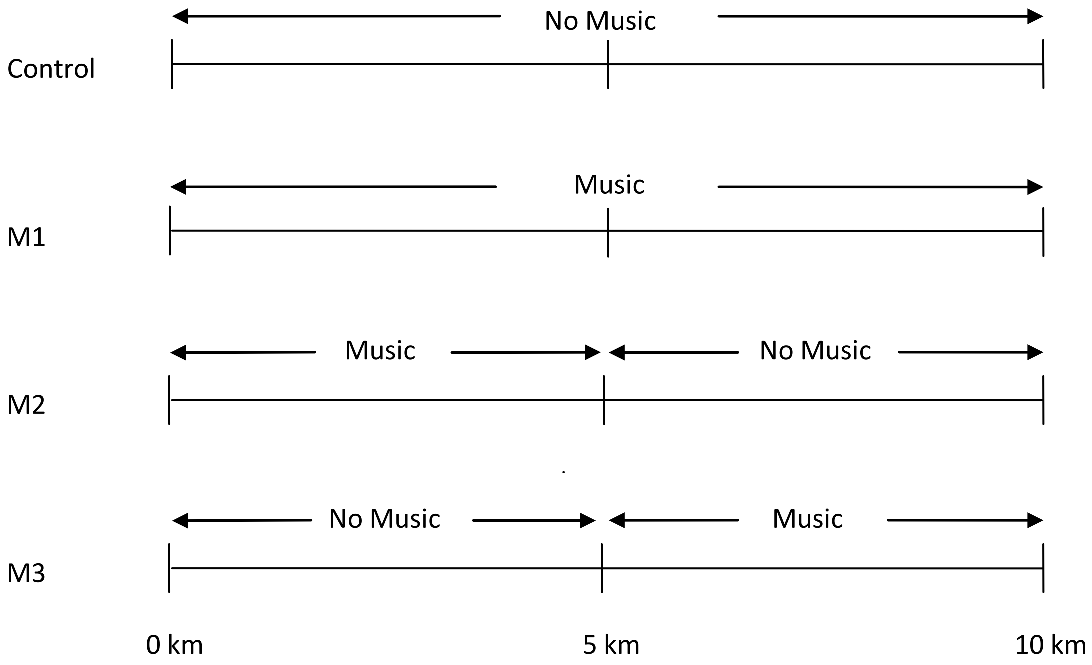

Figure 3.2. Schematic of music manipulation under each condition.

3.2.3 Measures

3.2.3.1 Performance variables. Overall race time was automatically recorded by the Velotron Software at the end of every time trial. Speed, power output, and cadence were recorded continuously throughout the entire time trial by the internal software provided with the Velotron. These performance variables were subsequently averaged out into two halves – 1st half (0-5 km) and 2nd half (5-10 km) – for data analysis.

3.2.3.2 Ratings of perceived exertion and heart rate. Participants' perception of effort was determined using Borg's Category Ratio 10 scale (CR10; Borg, 1998). The scale has a range of 0 (*nothing at all*) to 10 (*very very hard*), proceeded by a dot denoting maximal exertion. Validity of the scale has been demonstrated in terms of its correlations with common physiological indices such as heart rate and $\dot{V}O_2$ (r = .80 to .95; Borg). High intratest (r = .93) and retest (r = .83 to .94) reliability have also been reported (Borg).

Participants' heart rates were measured using a chest strap and a heart rate monitor wristwatch (Polar Accurex Plus; Polar, Kempele, Finland). Both heart rate and RPE were measured at four different distance intervals during the time trial: 2.5 km, 5 km, 7.5 km, and 10 km. These distance points were chosen to maintain consistency with previous research of a similar nature and thus facilitate comparison (e.g. Atkinson et al., 2004; Lim et al., 2009).

3.2.3.3 Affective valence and arousal. Affective valence was assessed using Rejeski's (1985) Feeling Scale (FS). It is an 11-point, single-item measure, with a scale ranging from -5 to +5. Descriptive markers are provided at zero ("Neutral"), and at all odd integers, ranging from "Very Bad" (-5) to "Very Good" (+5). The FS has shown correlations in the range .51-.88 with the valence scale of the Self-assessment Manikin (SAM; Lang, 1980), and in the range .41-.59 with the valence scale of the Affect Grid (AG; Russell, Weiss, & Mendelsohn, 1989). According to Ekkekakis and Petruzzello (2002), the FS is a suitable and valid measurement of in-task affective valence; particularly because it limits respondent overload and is thus appropriate for repeated assessments during an exercise protocol.

Arousal was measured using the Felt Arousal Scale (FAS) of the Telic State Measure (Svebak & Murgatroyd, 1985). It is a six-point, single-item measure with a scale ranging from 1 to 6. Anchors are provided at 1 (Low Arousal) and 6 (High Arousal). The FAS has exhibited correlations between .45 and .70 with the arousal scale of the SAM and .47 to .65 with the arousal scale of the AG. In-task affective valence and arousal were measured at four distance intervals during the time trial: 0.5 km, 4.5 km, 5.5 km, and 9.5 km. These distance points were chosen in order to examine the impact of music removal and introduction.

3.2.4 Data Analysis

The four distance points assessed for heart rate, RPE, affective valence, and arousal were averaged out to give two scores each: 1st half (0-5 km) and 2nd half (5-10 km). This was done to provide a more comprehensive means of analysing and reporting the data. Given that the order of tracks was randomised for each participant across every trial, individual psychological and psychophysical responses may be expected to differ depending on the track that was heard at the point of measurement. Accordingly, a decision was taken to average the data points for each of the two halves of the 10-km task in order to present a more balanced account of responses.

Raw data were screened for univariate outliers using standardised scores ($-3.29 \leq z \geq 3.29$), and where relevant, the Mahalanobis distance method with $p < .001$ was used to identify multivariate outliers (Tabachnick & Fidell, 2007, p. 73). These procedures were carried out for each separate analysis and for each cell within each analysis. Further, standard skewness and kurtosis were examined in each cell of the analysis to check for deviations from normality (Std. Skew/Kurt.≥ 1.96; Vincent, 2005, p. 89). Tests were also carried out to ensure the data met the relevant parametric assumptions. A one-way repeated-measures ANOVA was applied to the overall race time, while all other variables were analysed using a two-factor 4 (Condition) x 2 (Distance), within-subjects ANOVA. Univariate tests were corrected for sphericity violations where necessary, using Greenhouse-Geisser adjusted *F* values. Analyses were performed using SPSS for Windows Version 15.0 (SPSS Inc., Chicago, IL).

3.3 Results

Performance variables were presented first, followed by psychophysical and finally psychological measures. No univariate and multivariate outliers were identified for any variable during the data screening process, although there were violations of normality for time to completion, speed, and heart rate. Standard skewness and kurtosis, and descriptive statistics for each dependent variable are presented in Table 3.1 and Table 3.2 respectively. The specific details of each analysis will be covered in the subsequent sections.

3.3.1 Time to Completion

Data screening revealed no univariate outliers, but there were violations of normality in tests of standard skewness and kurtosis; the dataset for M2 was severely positively skewed and severely leptokurtic (see Table 3.1). Accordingly, transformation of data was carried out in an attempt to normalise the distribution. A square root transformation was first carried out

(Tabachnick & Fidell, 2007, p. 78); although this reduced the severity of violations of skewness and kurtosis, the violations of non-normality were not eradicated. A log transformation was then applied (Tabachnick & Fidell), which resulted in the normalisation of the dataset, and therefore the transformed data were used for analysis. Given that the data now met the relevant parametric assumptions, ANOVA was retained as the test of significance.

Mauchly's test of sphericity revealed no violation for the assumption of sphericity ($W = .829$, $\varepsilon = .905$, $p = .57$), thus no adjustment was applied to F ratio data. The condition effect was significant, $F(3, 69) = 7.02$, $p < .001$, $\eta_p^2 = .23$, and accounted for 23% of the variance, representing a large effect. Follow-up pairwise comparisons with Bonferroni adjustment indicated that trials were significantly faster under M1 ($p = .01$, $M = -43.42$, 95% CI = [-78.17, -8.66]) and M3 ($p = .03$, $M = -26.54$, 95% CI = [-51.77, -1.31]) when compared to control, while M2 did not significantly differ ($p > .05$) when compared against the other three conditions (see Table 3.2). There was also no significant difference between M1 and M3, although participants under the former condition were 17 s quicker on average.

3.3.2 Speed

Data screening revealed no univariate outliers, although tests of standard skewness and kurtosis showed minor violations of normality (see Table 3.1); minor negative skewness was observed in M2 for the 1st half. Given that the violations of normality were not due to outliers (Tabachnick & Fidell, 2007, p. 78), and violation of the ANOVA assumption of normality does not drastically affect the F value (Vincent, 2005, p. 163), ANOVA was retained as the test of significance. Mauchly's test of sphericity revealed no violations for the assumption of sphericity for the Condition x Distance interaction ($W = .647$, $\varepsilon = .818$, $p = .09$), or the condition main effect ($W = .779$, $\varepsilon = .863$, $p = .37$). Sphericity was not an issue for the main effect of distance, considering it had less than three levels. Accordingly, no adjustments were applied to the analysis of distance.

3.3.2.1 Condition x Distance interaction. There was a significant Condition x Distance interaction, $F(3, 69) = 7.38$, $p < .001$, $\eta_p^2 = .24$, and this accounted for 24% of the variance explained by the interaction, representing a moderate effect. Separate ANOVAs were conducted to determine the source of the interaction. The introduction and removal of the musical stimulus at different distance intervals appeared to influence the speeds at which participants chose to cycle. In the first half of the trial, speed was significantly higher in M1 ($p = .003$) and M2 ($p = .008$) compared to control, while M3 was not significantly different to these conditions ($p > .05$). The opposite however, was observed for the second half; M1 ($p = .018$) and M3 ($p = .017$) showed significantly higher speeds compared to control. Moreover, speed in M1 was significantly higher compared to M2 ($p = .016$). Thus, In M2, the removal of music in the second half of the 10-km time trial resulted in a concomitant decrease in speed, while the introduction of music in M3 for the second half led to participants achieving higher speeds when compared to the first half (see Figure 3.3).

Table 3.1

Standard Skewness and Kurtosis for each Dependent Variable, under Each Condition, across both Halves of the Time Trial

Variable	Condition	Distance	Std. Skew.	Std. Kurt.
Speed	Control	1st half	-0.84	0.27
		2nd half	-0.89	-0.76
	M1	1st half	-0.65	-0.42
		2nd half	0.22	-0.58
	M2	1st half	-1.88	2.54*
		2nd half	-1.20	0.53
	M3	1st half	-1.13	-0.28
		2nd half	-0.56	-0.37
Power Output	Control	1st half	0.28	0.47
		2nd half	-0.39	-0.75
	M1	1st half	0.07	-0.47
		2nd half	0.72	-0.40
	M2	1st half	-0.31	1.68
		2nd half	-0.46	-0.16
	M3	1st half	-0.39	-0.32
		2nd half	0.20	-0.04
Cadence	Control	1st half	-0.45	0.69
		2nd half	-1.23	0.07
	M1	1st half	-0.63	-0.12

(table continues)

Table 3.1 (continued)

		2nd half	-0.05	-0.81
	M2	1st half	-1.26	0.39
		2nd half	-1.76	0.70
	M3	1st half	0.40	-0.97
		2nd half	-0.47	-0.88
Heart Rate	Control	1st half	-1.04	-0.32
		2nd half	-2.09*	1.57
	M1	1st half	0.18	-0.58
		2nd half	0.27	0.16
	M2	1st half	-0.89	0.98
		2nd half	0.03	1.60
	M3	1st half	-2.01*	0.83
		2nd half	-0.24	-0.28
RPE	Control	1st half	0.89	-1.07
		2nd half	0.39	-1.01
	M1	1st half	0.58	-1.33
		2nd half	-0.98	-0.71
	M2	1st half	1.32	-0.71
		2nd half	-0.13	-0.93
	M3	1st half	1.13	-0.62
		2nd half	-0.06	-1.18
In-task Valence	Control	1st half	0.52	0.66

(table continues)

Table 3.1 (continued)

		2nd half	-0.04	-0.17
	M1	1st half	-0.80	0.27
		2nd half	-0.34	-0.78
	M2	1st half	0.31	0.11
		2nd half	0.30	-1.15
	M3	1st half	0.07	-1.20
		2nd half	-1.00	-0.38
In-task Arousal	Control	1st half	-0.32	-1.22
		2nd half	0.52	-0.72
	M1	1st half	-0.97	1.79
		2nd half	-0.08	-0.27
	M2	1st half	-1.11	0.43
		2nd half	-0.62	0.98
	M3	1st half	-1.95	-0.08
		2nd half	0.47	-1.39

* $p < .05$.

Table 3.2

Overall Condition Means (SD) and Main Effects for all Dependent Variables

Variables		*M*	*SD*	*F*(3, 69)	Source of diff.
Time to Completion (s)	Control	1173	109	7.02*	M1, M3 < Control
	M1	1129	90		
	M2	1153	110		
	M3	1146	97		
Speed (km/h)	Control	31.07	2.72	7.30*	M1, M3 > Control
	M1	32.19	2.50		
	M2	31.59	2.72		
	M3	31.71	2.52		
Power Output (W)	Control	170.67	36.27	7.65*	M1, M3 > Control
	M1	186.18	36.43		
	M2	178.37	36.48		
	M3	179.41	34.73		
Cadence (rpm)	Control	91.12	12.09	.39	
	M1	92.08	10.43		
	M2	91.71	10.98		
	M3	92.24	10.15		

(table continues)

Table 3.2 (continued)

Heart Rate (bpm)	Control	164.11	15.67		
	M1	171.89	10.44	6.94*	M1, M3 > Control
	M2	168.29	14.61		
	M3	168.49	12.92		
RPE	Control	5.69	1.89		
	M1	6.02	1.88	2.09	
	M2	5.82	1.95		
	M3	5.84	1.81		
Affective Valence	Control	1.07	1.47		
	M1	1.35	1.66	1.13	
	M2	1.32	1.83		
	M3	1.48	1.62		
Arousal	Control	3.47	1.02		
	M1	4.18	.88	9.13*	M1, M2, M3 > Control
	M2	4.01	.90		
	M3	4.04	.85		

Note. Bonferroni adjustments made for multiple comparisons.

**p* < .001.

3.3.2.2 Condition main effect. There was a significant main effect for condition, $F(3, 69) = 7.29$, $p < .001$, $\eta_p^2 = .24$, and this independent variable manipulation accounted for 24% of the variance,representing a large effect. Follow-up pairwise comparisons with Bonferroni adjustment indicated that mean race speed was significantly higher in M1 ($p = .01$, $M = 1.13$, 95% CI = [.28, 1.97]) and M3 ($p = .03$, $M = .64$, 95% CI = [.05, 1.24]) when compared to control, although M2 did not significantly differ ($p = .24$) from the other three conditions. There was also no significant difference ($p = .39$) between M1 and M3. Nonetheless participants exposed to music for the entire 10 km were .5 km/h faster on average compared to when cycling to music only for the last half of the time trial (see Table 3.2).

3.3.2.3 Distance main effect. There was a significant main effect for distance, $F(1, 23) = 5.67$, $p = .03$, $\eta_p^2 = .20$, and this independent variable manipulation accounted for 20% of the variance, representing a large effect. Follow-up pairwise comparisons with Bonferroni adjustment indicated that mean race speed was significantly higher ($p = .03$, $M = .51$, 95% CI = [.07, .96]) in the second half when compared to the first half of the time trial (see Figure 3.3).

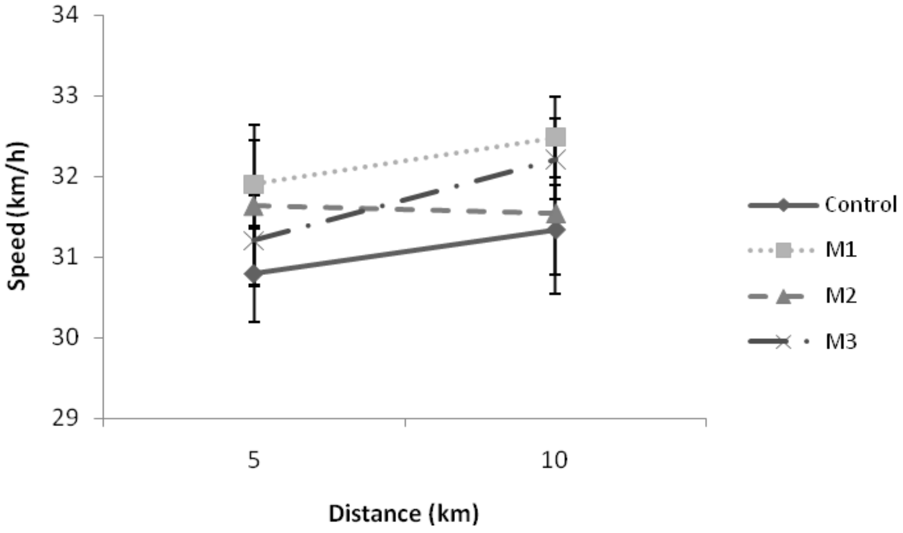

Figure 3.3. Condition x Distance interaction trendlines for mean cycling speed. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

3.3.3 Power Output

Data screening revealed no univariate outliers, and tests of standard skewness and kurtosis indicated that there were no violations of normality (see Table 3.1). Given that the relevant parametric assumptions were met, the ANOVA was retained as the test of significance. Mauchly’s test of sphericity revealed no violations for the assumption of sphericity for Condition x Distance interaction ($W = .639$, $\varepsilon = .819$, $p = .08$) and condition ($W = .671$, $\varepsilon = .790$, $p = .12$). Sphericity was not an issue for the main effect of distance, considering it had less than three levels. Accordingly, no adjustments were applied to the analysis of distance.

3.3.3.1 Condition x Distance interaction. There was a significant Condition x Distance interaction, $F(3, 69) = 8.30$, $p < .001$, $\eta_p^2 = .27$, and the manipulation of these independent variables accounted for 27% of the variance explained by the interaction, representing a moderate effect. Separate ANOVAs were conducted to determine the source of the interaction. The introduction and removal of the musical stimulus at different distance intervals appeared to influence the power output generated by participants. In the first half of the trial, power output was significantly higher in M1 ($p = .003$) and M2 ($p = .002$) compared to control, while M3 was not significantly different to these conditions ($p > .05$). The opposite however, was observed for the second half; M1 ($p = .019$) and M3 ($p = .006$) showed significantly higher power outputs compared to control. Moreover, power output in M1 was significantly higher compared to M2 ($p = .011$). Thus, the introduction and removal of the musical stimulus at different intervals appears to affect the power output generated by participants; in M2, the removal of music in the second half of the 10-km time trial resulted in lower power outputs when compared to the first half, while the introduction of music in M3 for the second half allowed participants to achieve higher power outputs compared to the first half (see Figure 3.4).

3.3.3.2 Condition main effect. There was a significant main effect for condition, $F(3, 69) = 7.65$, $p < .001$, $\eta_p^2 = .25$, and this independent variable manipulation accounted for 25% of the variance, representing a large effect. Follow-up pairwise comparisons with Bonferroni adjustment indicated that mean power output was significantly higher in M1 ($p = .01$, $M = 15.50$, 95% CI = [3.95, 27.06]) and M3 ($p = .02$, $M = 8.74$, 95% CI = [1.13, 16.34]) when compared to control, while M2 did not differ significantly ($p > .05$) when compared with the other three conditions. There was also no significant difference between M1 and M3 ($p = .50$), although participants under the former condition were generating power outputs of 6.77 W more on average (see Table 3.2).

3.3.3.3 Distance main effect. There was a significant main effect for distance, $F(1, 23) = 7.65$, $p < .001$, $\eta_p^2 = .25$, and this independent variable manipulation accounted for 64% of the variance, representing a large effect. Follow-up pairwise comparisons with Bonferroni adjustment indicated that mean power output was significantly higher ($p = .01$, $M = 7.57$, 95% CI = [1.91, 13.23]) in the second half when compared to the first half of the time trial (see Figure 3.4).

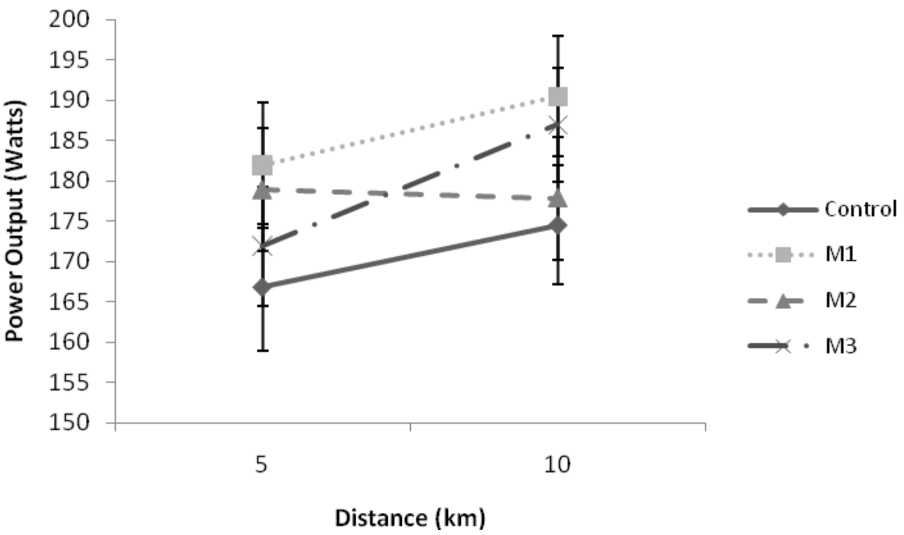

Figure 3.4. Condition x Distance interaction trendlines for mean power output. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

3.3.4 Cadence

Data screening revealed no univariate outliers, and tests of standard skewness and kurtosis indicated that there were no violations of normality (see Table 3.1). Given that the relevant parametric assumptions were met, the ANOVA was retained as the test of significance. Mauchly's test of sphericity no violations for the assumption of sphericity for Condition x Distance interaction (W = .777, ε = .856, p = .36) and condition (W = .768, ε = .841, p = .33). Sphericity was not an issue for the main effect of distance, considering it had less than three levels. Accordingly, no adjustments were applied to the analysis of distance.

3.3.4.1 Condition x Distance interaction. There was a significant Condition x Distance interaction, $F(3, 69) = 8.37$, $p < .001$, $\eta_p^2 = .27$, and the manipulation of these independent variables accounted for 27% of the variance explained by the interaction, representing a moderate effect. Under control and M1, participants appear to have a similar cadence pattern where cadence was relatively consistent until the final kilometre, which was characterised by a sharp rise, while under M2 and M3, cadence was very much higher in the segments with music accompaniment compared to the segments without music (see Figure 3.5).

3.3.4.2 Condition main effect. There was no significant main effect for condition, $F(3, 69) = .39$, $p = .76$, $\eta_p^2 = .02$, and this independent variable manipulation accounted for 2% of the variance. Participants cycled at a mean cadence of 91-92 rpm across all trials, with little variation between trials (see Table 3.2).

3.3.4.3 Distance main effect. There was a significant main effect for distance, $F(1, 23) = 5.04$, $p = .04$, $\eta_p^2 = .18$, and this independent variable manipulation accounted for 18% of the variance, representing a large effect. Follow-up pairwise comparisons with Bonferroni adjustment indicated that mean cycling cadence was significantly higher ($p = .04$, $M = 1.56$, 95% CI = [.12, 2.99]) in the second half when compared to the first half of the time trial (see Figure 3.5).

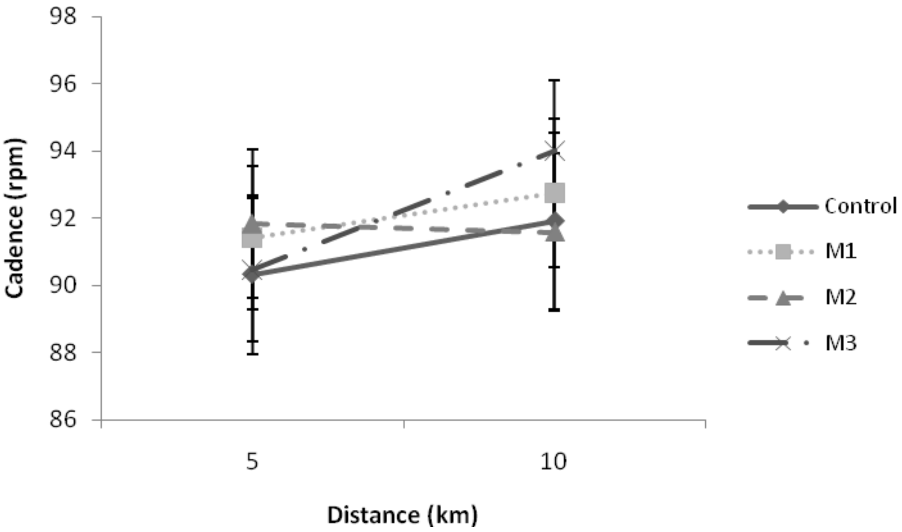

Figure 3.5. Condition x Distance interaction trendlines for mean cycling cadence. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

3.3.5 Heart Rate

Data screening revealed no univariate outliers, although tests of standard skewness and kurtosis showed minor violations of normality; minor negative skewness was observed for control in the second half, and M3 in the first half (see Table 3.1). Given that the violations of normality were not due to outliers (Tabachnick & Fidell, 2007, p. 78), and violation of the ANOVA assumption of normality does not drastically affect the *F* value (Vincent, 2005, p. 163), the ANOVA was retained as the test of significance. Mauchly’s test of sphericity revealed no violations for the assumption of sphericity for the Condition x Distance interaction ($W = .851$, $\varepsilon = .909$, $p = .62$), or the condition main effect ($W = .721$, $\varepsilon = .848$, $p = .21$). Sphericity was not an issue for the main effect of distance, considering it had less than three levels. Accordingly, no adjustments were applied to the analysis of distance.

3.3.5.1 Condition x Distance interaction. There was a significant Condition x Distance interaction, $F(3, 69) = 9.54$, $p < .001$, $\eta_p^2 = .29$, and the manipulation of these independent variables accounted for 29% of the variance explained by the interaction, representing a large effect. Separate ANOVAs were conducted to determine the source of the interaction. The introduction and removal of the musical stimulus at different distance intervals had an influence on participants' heart rate. In the first half of the trial, heart rate was significantly higher in M1 ($p = .007$) and M2 ($p = .011$) compared to control, while M3 was not significantly different to these conditions ($p > .05$). The opposite however, was observed for the second half; participants in M1 ($p = .011$) and M3 ($p = .015$) reported significantly higher heart rates compared to control. Moreover, heart rate in M1 was significantly higher compared to M2 ($p = .029$). Thus, there was an increase in heart rate over time for all conditions, although the rate of increase differed across conditions (see Figure 3.6).

3.3.5.2 Condition main effect. There was a significant main effect for condition, $F(3, 69) = 6.94$, $p < .001$, $\eta_p^2 = .23$, and this independent variable manipulation accounted for 23% of the variance, representing a large effect. Follow-up pairwise comparisons with Bonferroni adjustment indicated that heart rate was significantly higher in M1 ($p = .01$, $M = 7.82$ bpm, 95% CI = [1.82, 13.83]) and M3 ($p = .02$, $M = 4.56$ bpm, 95% CI = [.51, 8.59]) when compared to control, although there was no significant difference between M1 and M3 ($p = .389$). There were also no differences between M2 and the remaining three conditions ($p > .05$; see Table 3.2).

3.3.5.3 Distance main effect. There was a significant main effect for distance, $F(1, 23) = 195.70$, $p < .001$, $\eta_p^2 = .90$, and this independent variable manipulation accounted for 90% of the variance, representing a large effect. Heart rate was significantly higher ($p < .001$, $M = 12.46$ bpm, 95% CI = [10.62, 14.31]) in the second half of the time trials when compared to the first half (see Figure 3.6).

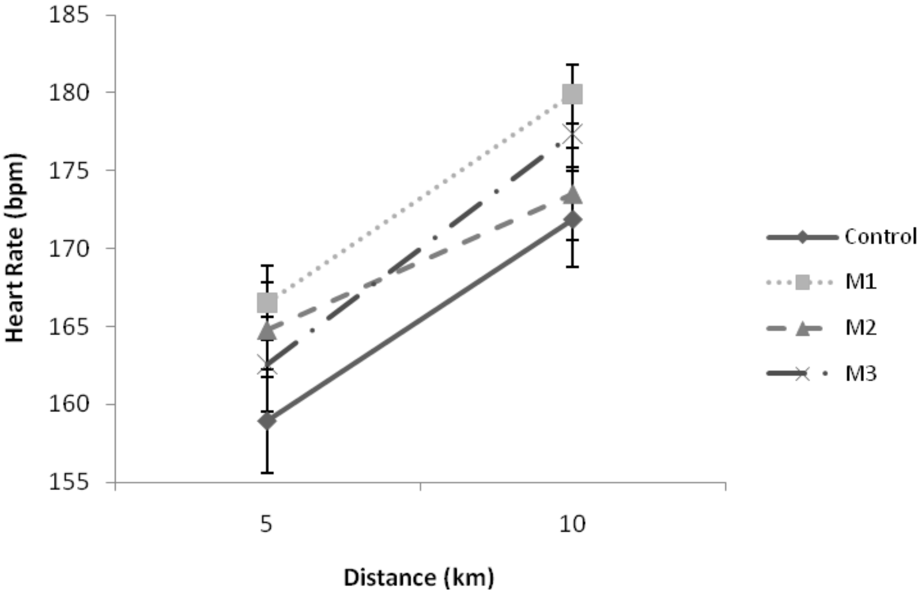

Figure 3.6. Condition x Distance interaction trendlines for mean heart rate. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

3.3.6 Ratings of Perceived Exertion

Data screening revealed no univariate outliers, and tests of standard skewness and kurtosis indicated that there were no violations of normality (see Table 3.1). Given that the relevant parametric assumptions were met, ANOVA was retained as the test of significance. Mauchly's test of sphericity revealed no violations for the assumption of sphericity for the Condition x Distance interaction ($W = .771$, $\varepsilon = .842$, $p = .34$), or the condition main effect ($W = .775$, $\varepsilon = .844$, $p = .35$). Sphericity was not an issue for the main effect of distance, considering it had less than three levels. Accordingly, no adjustments were applied to the analysis of distance.

3.3.6.1 Condition x Distance interaction. There was a no significant Condition x Distance interaction, *F*(3, 69) = 1.06, $p = .373$, $\eta_p^2 = .05$, and the manipulation of these independent variables accounted for 5% of the variance explained by the interaction. The presence of music did not induce any changes in participants' perception of effort over the course of the time trials (see Figure 3.7).

3.3.6.2 Condition main effect. There was no significant main effect for condition, *F*(3, 69) = 2.09, $p = .109$, $\eta_p^2 = .08$, and this independent variable manipulation accounted for 8% of the variance. Although this effect size is considered moderate, there was no discernible difference for RPE across conditions (see Table 3.2).

3.3.6.3 Distance main effect. There was a significant effect for distance, *F*(1, 23) = 130.60, $p < .001$, $\eta_p^2 = .85$, and this independent variable manipulation accounted for 85% of the variance, representing a very large effect. Perceived exertion was significantly higher ($p < .001$, $M = 1.97$, 95% CI = [1.61, 2.33]) in the second half of the time trials compared to the first half (see Figure 3.7).

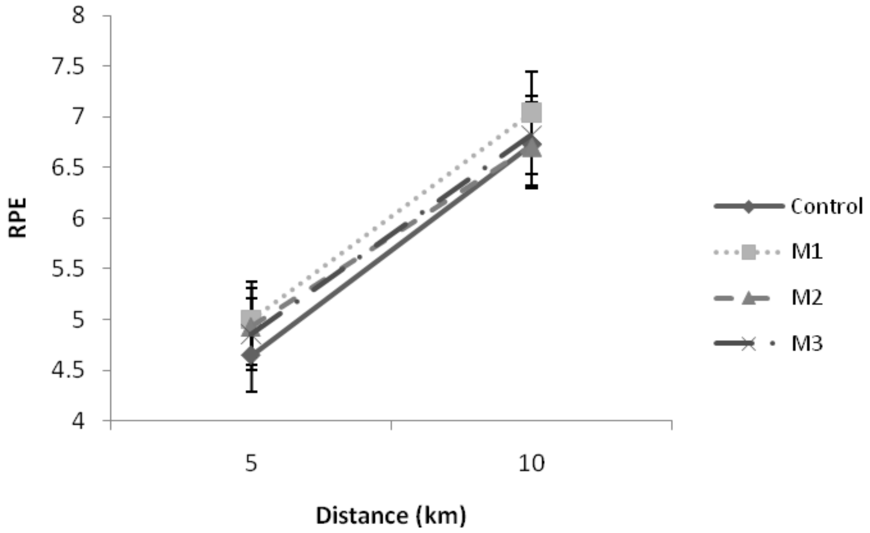

Figure 3.7. Condition x Distance interaction trendlines for mean RPE. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

3.3.7 In-task Affective Valence

Data screening revealed no univariate outliers, and tests of standard skewness and kurtosis indicated that there were no violations of normality (see Table 3.1). Given that the relevant parametric assumptions were met, ANOVA was retained as the test of significance. Mauchly's test of sphericity revealed no violations for the assumption of sphericity for the Condition x Distance interaction ($W = .740$, $\varepsilon = .834$, $p = .26$), or the condition main effect ($W = .611$, $\varepsilon = .741$, $p = .06$). Sphericity was not an issue for the main effect of distance, because it comprised fewer than three levels. Accordingly, no adjustments were applied to the analysis of distance.

3.3.7.1 Condition x Distance interaction. There was a significant Condition x Distance interaction, $F(3, 69) = 3.62$, $p = .019$, $\eta_p^2 = .14$, and the manipulation of these independent variables accounted for 14% of the variance explained by the interaction, representing a moderate effect. Separate ANOVAs were conducted to determine the source of the interaction. No significant differences were found across conditions during the first half (p > .05) or the second half (p > .05) of the time trial. Nonetheless, M3 appeared to attenuate the decline in affective valence far better than the other conditions (see Figure 3.8).

3.3.7.2 Condition main effect. There was no significant main effect for condition, $F(3, 69) = 1.13$, $p = .343$, $\eta_p^2 = .05$, and this independent variable manipulation accounted for 5% of the variance. Essentially, there were no differences in mean affective valence when the music conditions were compared against the control condition (see Table 3.2).

3.3.7.3 Distance main effect. There was a significant main effect for distance, $F(1, 23) = 7.52$, $p = .012$, $\eta_p^2 = .25$, and this independent variable manipulation accounted for 25% of the variance. There was a significant decline ($p = .01$, $M = .51$, 95% CI = [-.90, -.13]) in mean affective valence from the first to the second half of the time trial (see Figure 3.8).

3.3.8 In-task Arousal

Data screening revealed no univariate outliers, and tests of standard skewness and kurtosis indicated that there were no violations of normality (see Table 3.1). Given that the relevant parametric assumptions were met, ANOVA was retained as the test of significance. Mauchly's test of sphericity revealed no violations for the assumption of sphericity for the Condition x Distance interaction ($W = .800$, $\varepsilon = .882$, $p = .44$), or the condition main effect ($W = .824$, $\varepsilon = .901$, $p = .52$). Sphericity was not an issue for the main effect of distance, considering it had less than three levels. Accordingly, no adjustments were applied to the analysis of distance.

3.3.8.1 Condition x Distance interaction. There was a significant Condition x Distance interaction, *F*(3, 69) = 11.87, $p < .001$, $\eta_p^2 = .34$, and the manipulation of these independent variables accounted for 34% of the variance explained by the interaction, representing a large effect. Separate ANOVAs were conducted to determine the source of the interaction. The introduction and removal of the musical stimulus at different distance intervals had an influence on participants' arousal levels. In the first half of the trial, arousal was significantly higher in M1 ($p = .002$) and M2 ($p = .008$) compared to control, while M3 was not significantly different to these conditions ($p > .05$). The opposite however, was observed for the second half; participants in M1 ($p = .004$) and M3 ($p > .001$) reported significantly higher heart rates compared to control. In addition, arousal in M3 was significantly higher compared to M2 ($p = .043$). Thus, there was a steady increase in arousal from the first to the second half of the time trial for control and M1, while M3 was associated with a sharp rise in the latter stages, especially in comparison to M2. Participants in M2 reported a decrease in arousal from the first to the second half of the time trial (see Figure 3.9).

3.3.8.2 Condition main effect. There was a significant main effect for condition, *F*(3, 69) = 9.13, $p < .001$, $\eta_p^2 = .28$, and this independent variable manipulation accounted for 28% of the variance, representing a large effect. Follow-up pairwise comparisons with Bonferroni adjustment indicated that mean arousal was significantly higher for M1 ($p = .001$, $M = .71$, 95% CI = [.24, 1.19]), M2 ($p = .02$, $M = .54$, 95% CI = [.06, 1.02]), and M3 ($p = .002$, $M = .57$, 95% CI = [.19, .96]) when compared to control, although there was no significant differences ($p > .05$) among the experimental conditions (see Table 3.2).

3.3.8.3 Distance main effect. There was a significant main effect for distance, $F(1, 23) = 7.77$, $p = .010$, $\eta_p^2 = .25$, and this independent variable manipulation accounted for 25% of the variance, representing a large effect. There was a significant increase ($p = .01$, $M = .29$, 95% CI = [.07, .50]) in mean arousal from the first to the second half of the time trial (see Figure 3.9).

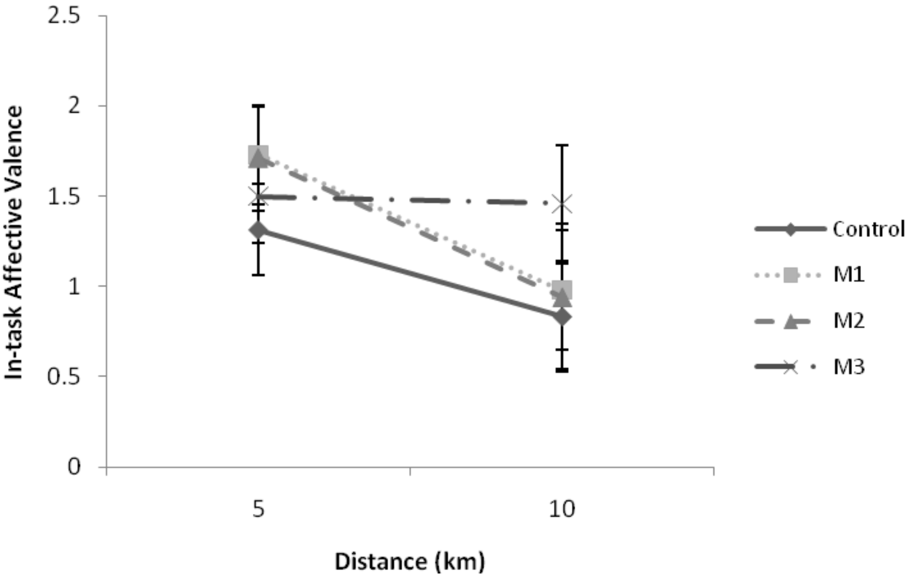

Figure 3.8. Condition x Distance interaction trendlines for mean in-task affective valence. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

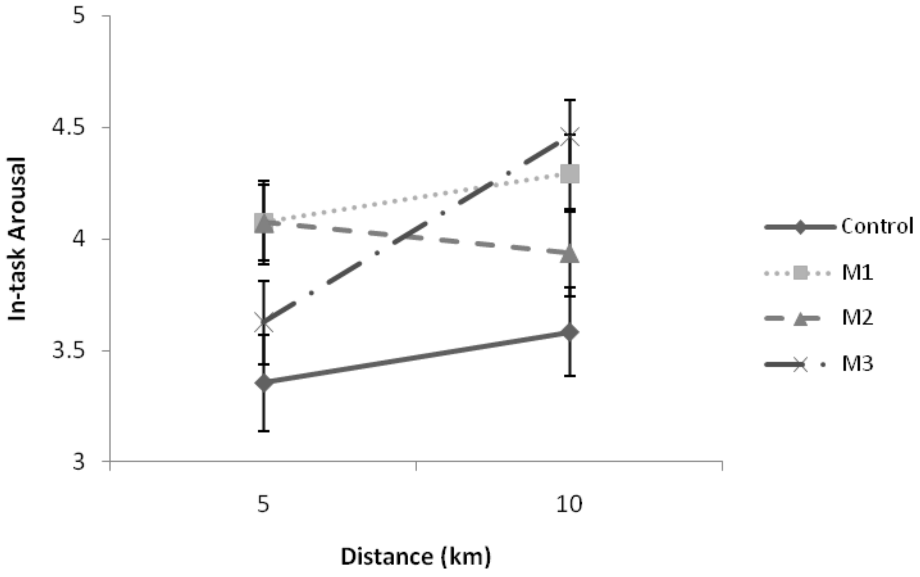

Figure 3.9. Condition x Distance interaction trendlines for mean in-task arousal. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

3.4 Discussion

The aim of the present study was to investigate the ergogenic, psychophysical, and psychological effects of differentiated music exposure on 10-km cycling time trial performance. It was hypothesised: (a) that cycling times would be faster for all music conditions compared to a no music control condition; and (b) that participants would record faster times in M3 compared to M2. The null hypothesis was tested for the comparison between M1 and the other two music conditions, as it was unclear whether participants cycling with music throughout the entire 10 km would perform better when compared to the other music conditions; (c) ratings of perceived exertion would not be significantly different if participants recorded faster cycling times under music conditions, while similar cycling times would result in a significant reduction in RPE with music accompaniment; and (d) more positive affective valence and higher arousal responses were expected in the music conditions. Significant Condition x Distance interactions were observed for all dependent variables with the exception of RPE. There were also significant condition main effects identified for cycling times, speed, power output, heart rate, and arousal, and significant distance main effects for all variables. The present findings are discussed in greater detail in the subsequent sections, starting with performance variables, followed by heart rate and RPE, and the psychological responses of affective valence and arousal.

3.4.1 Performance

Hypothesis (a) was partially supported; significant faster times were recorded only for trials M1 and M3 in comparison to control. Although times for M2 were faster than control, the difference did not reach statistical significance ($p > .05$). There were also no significant differences across the three experimental conditions, thus hypothesis (b) was refuted. Faster cycling times for M1 and M3 were a result of increases in speed and power output, and most likely attributable to the music interventions. Under M1, the speed profile was similar to control, the only difference being that participants were achieving consistently higher speeds. Cadence profiles for both M1 and control were identical, suggesting that participants in M1 were generating greater velocity independent of pedalling frequency. In M3, the speed profile was similar to control during the first half, but there was an increase in speed for the second half of the time trial following the introduction of music. The converse was true for M2, although the difference did not reach statistical significance ($p > .05$). Further, a significant interaction for cadence indicates that pedalling frequency is influenced by the manipulation of music exposure. Therefore it is clear that performance in the present study was not only affected by the presence of music, but also by the way in which it was presented during the task.

Atkinson et al. (2004) also reported faster cycling times when participants were exposed to music throughout a 10-km cycling time trial; nonetheless their speed profiles were only significantly higher ($p < .05$) for the first half of the time trial, after which speed decreased to a level similar to control. There are two plausible explanations for the difference in speed profiles between Atkinson et al.'s study and the present one.

Firstly, the music selection process employed by Atkinson et al. was not guided by the recommendations in the literature (e.g., Karageorghis et al., 2006; Karageorghis et al., 1999). Specifically, the trance music was chosen by researchers and its motivational qualities were not given due consideration. Although the BMRI was administered post-task, and results seem to indicate that participants in Atkinson et al.'s study deemed the trance music to be motivating, it may not have been considered as motivating when compared to other music genres. Further, limitations inherent in the BMRI (see Karageorghis et al., 2006) may have influenced the rating process and contributed to a flawed motivational quotient. For example, the BMRI was developed specifically for exercise instructors, and not exercise participants. Thus, one could question the reliability and validity of the inventory when used by anyone other than exercise instructors. It is plausible that the trance music may not have been sufficiently motivating for participants to sustain their higher starting speeds once fatigue accumulates as the time trial proceeds from the first to the second half. In the present study, participants under M1 registered higher speeds throughout when compared to control. This indicates that appropriately selected music enabled participants to generate higher speeds even when fatigued.

The other explanation for the difference in speed profiles between Atkinson et al.'s (2004) study and the present study concerns participants having knowledge of the intervention prior to commencement of the trial; unlike the present study, both Atkinson et al. and Lim et al.'s (2009) participants were not blinded to the music intervention. They were informed of the nature of music exposure prior to the start of each time trial, although they were not told whether the provision of music would be beneficial to their performance. Therefore their participants were fully aware of the nature and duration of the music intervention prior to commencing each trial. It is possible that participants might have formulated a suitable cycling strategy (i.e., fast start) based around the exposure of music.

The speed profiles reported by Lim et al. (2009) were similar to those of Atkinson et al. (2004); although no significant main effects were observed, there was a significant Condition x Distance interaction for cycling speed. They observed that participants exposed to music in the second half of a 10-km cycling time trial attained higher speeds before the introduction of music, and not during the period of music exposure. Further, participants exposed to music for the first half of the 10-km time trial exhibited a similar speed profile when compared to the trial where they did not have music.

Adopting the Central Governor Model of fatigue perspective (Noakes, St Clair Gibson, & Lambert, 2005), Lim et al. (2009) proposed that participants could have used the knowledge to pre-plan their racing strategies. Specifically, they speculated that knowing the sequence of music presentation allowed participants to formulate a racing strategy to complete the time trial in the best possible way, without severe disruption to internal homeostasis. Accordingly, when presented with music for only the second half of the cycling task, participants may have decided to cycle faster for the first 5 km of the time trial, with the foreknowledge that there would be musical accompaniment during the latter stages that would serve as a motivational tool to combat the possible increment in fatigue due to the heavier workload from the first half of the time trial.

It is entirely plausible that the aforementioned strategy was also adopted by Atkinson et al.'s (2004) participants. Although exposure to music in the Atkinson et al. study was for the entire duration of the time trial, their participants may have only considered music in the latter half of the time trial in the planning of their racing strategy and its effects on the overall performance outcome. Thus the initial increases in speed observed by Atkinson et al. were not a result of direct music exposure but rather that their participants knew that music was available in the second half of the time trial, and planned their cycling strategy accordingly. This view is partially corroborated by the findings of Lim et al. (2009); in a time trial with music presented in the first half, no corresponding increases in velocity were observed during periods of music exposure. However in a separate trial with music presented in the latter half, participants recorded higher speeds in the initial stages of the time trial.

In the present study, participants were blinded to the experimental conditions, and accordingly, would not have been able to devise a racing strategy that accounted for the changes to the external environment prior to commencing the time trials. Rather, any change in racing strategy based on the introduction/removal of music would have been made in vivo. Nonetheless, proponents of the Central Governor Model (Noakes, St Clair Gibson, & Lambert, 2005) have suggested that the theory allows for changes to be made at any point in a given task. This view is supported in the speed profiles observed in this study: Participants generated greater velocities only in the presence of music, indicating that racing strategies can be altered at any time. Thus it would appear that participants were able to increase their work output according to situational changes (i.e., the provision of music), and in the process alter a pre-planned racing strategy (Lim et al., 2009) without severe disruption to the initial parameters set to maintain the internal physiological environment and functioning.

The ability to work harder under the influence of music would suggest some form of *reserve* (mental, physiological, or both) that can be drawn upon under certain circumstances. This reserve is almost analogous to the fuel reserves found in automotive vehicles, and allows the body to continue operating for a short duration after depletion of the main resources. Indeed, Crewe, Tucker, and Noakes (2008) have postulated that when participants undertake an exercise task without any indication of the endpoint, a conservative strategy is chosen which results in underperformance and exercise cessation with some level of physiological reserve. The existence of this reserve has been suggested as a possible explanation for the characteristic *end spurt* during endurance-type protocols such as cycling time trials and marathons (St Clair Gibson et al., 2006; Tucker, Rauch, Harley, &

Noakes, 2004). In such instances, athletes approaching the finish line may have decided that there were sufficient resources available to increase the level of performance without compromising homeostatic functioning. Given current observations and past results (e.g., Atkinson et al., 2004; Lim et al., 2009), it would seem that this reserve is present even when knowledge of the endpoint is given, and it is much deeper than previously proposed. Further, this reserve can be drawn upon not only towards the end of a race but at various points within it, given the appropriate conditions (i.e., musical accompaniment).

Although the three experimental conditions did not significantly differ from each other, there was a minimum of a 15 s improvement in race time when participants cycled in the presence of music for the entire 10 km distance. Thus, it would seem that having musical accompaniment for the entire distance is potentially more favourable for performance compared to music presented in either half of the time trial. There are, however, situations wherein a fast start can be detrimental; races with an uphill profile or strong headwinds in the latter stages are best approached with higher than average power. Under such circumstances, cyclists may not be able to generate the optimal power output for the closing stages of a race if they start out too fast (Atkinson & Brunskill, 2000; Swain, 1997). Consequently, regulating power output via exposure to music in the latter parts of a race may lead to superior overall performance.

There is a paucity of research investigating the effects of appropriately chosen music on performance using an externally valid exercise protocol. Studies have either used the BMRI/BMRI-2 to select music for fixed intensity type tasks (e.g., Crust & Clough, 2006; Elliot et al., 2005; 2004), or used externally valid protocols but neglected the music selection process (e.g., Ferguson et al., 1994; Rendi et al., 2008). This makes comparison between the current findings and those of past studies quite challenging. Accordingly there is a need to conduct more research of a similar nature to the present study in order to fully comprehend the effects of well-selected music on performance.

3.4.2 Ratings of Perceived Exertion and Heart Rate

Given that improvements in performance were not accompanied by a corresponding increase in RPE, hypothesis (c) was supported. The present findings for RPE and heart rate appear to suggest that participants in the music trials were working harder physiologically to attain increases in speed but perceived themselves to be experiencing the same degree of exertion as in the control trial. Music appears to motivate participants to increase their level of effort, as evidenced by the elevated levels of heart rate compared to control. This notion is given greater strength by the significant interaction reported for heart rate; increases and decreases in heart rate coincided with the introduction and removal of music respectively (see Figure 3.6). Moreover, given that changes in heart rate and cycling speeds occur only in the presence of music it is unlikely that participants presented with music for the first half of the time trial were experiencing any carry-over effects during the latter stages. Elevations in heart rate might also rule out the possibility of movement efficiency/economy being the factor underlying superior performance with aysnchronous music; metabolic economy has been proposed as a mechanism for explaining the ergogenic effects of music, particularly of a synchronous nature (Karageorghis et al., 2009). Nonetheless, the lack of a direct measure of physiological efficiency such as $\dot{V}O_2$ or blood lactate makes it difficult to ascertain if this was indeed the case.

The lack of a significant reduction in perceived exertion under music influence is in stark contrast to extant theory and empirical research (see Karageorghis, 2008, for review). It is proposed that listening to music during submaximal exercise attenuates RPE by approximately 10% (Nethery, 2002). As detailed by Rejeski's (1985) parallel processing model, pleasant external stimuli such as music are capable of occupying limited attentional channels, thus preventing individuals from consciously experiencing internal sensations of fatigue. Nonetheless, this process only operates at low-to-moderate exercise intensities and is rendered ineffectual by high workloads (Boutcher & Trenske, 1990; Tenenbaum et al., 2004). An important point to note was that previous researchers documenting a reduction in RPE used submaximal exercise intensities of a fixed duration. Lim et al. (2009) proposed that the effects of music on RPE operate differently during self-paced exercise tasks and that music can have an impact on one's perception of effort, even if no significant differences are noted.

From a physiological perspective, an elevation in work output should generate higher levels of fatigue, unless any gains result from metabolic efficiency; this was unlikely to be the case in the current study given the increase in cardiovascular strain associated with superior performance. Therefore participants should have experienced greater amounts of fatigue as a result of generating faster speeds, and should in theory, have perceived higher levels of effort. Despite the fact that participants were cycling harder with music when compared to the no-music control, there were no significant increases in RPE. Accordingly, music would appear to have functioned as a distracting stimulus, by preventing the increased sensations of fatigue from registering onto focal awareness. In addition, the manipulation of music exposure did not affect how participants perceived the increased sensations of fatigue, as evident by the lack of a significant Condition x Distance interaction for RPE. The lack of change in RPE has also been observed in studies that have reported performance improvements under the influence of music (e.g., Rendi et al., 2008).

Results from the current study contradict those reported by Atkinson et al. (2004); in their study, increased work output was coupled by higher ratings of perceived exertion under the influence of music, suggesting that participants were conscious of their higher workloads and subjectively experiencing the strain. Nonetheless, present findings indicate that it is possible to attain greater performance gains without a concomitant increase in perceived exertion. Again, this difference might be attributable to the choice of music; it is highly plausible that the trance music selected by Atkinson et al. was not congruent with the musical preference of participants, and thus was not deemed to be sufficiently aesthetically pleasing to override the internal fatigue-related cues.

3.4.3 Affective Valence and Arousal

Current observations indicate that music did not positively influence overall mean in-task affective valence, but findings on arousal were as predicted. Accordingly, hypothesis (d) was partially supported. Nonetheless, although overall mean in-task affective valence did not significantly differ across trials, there was a significant difference over the course of the trial, and more importantly, a significant Condition x Distance interaction.

First and foremost, the finding that music per se did not positively influence participants' general affective valence is contrary to previous findings (Boutcher & Trenske, 1990; Elliot et al., 2004; 2005). It might be argued that the differences in exercise intensities accounted for the current observation. Previous studies employed submaximal workloads (Boutcher & Trenske; Elliot et al.); there is a possibility that participants were exercising below their ventilatory or lactate threshold. This is an important factor to consider: Ekkekakis, Hall, and Petruzzello (2008) reported that physically active young adults exercising at intensities above ventilatory threshold (T_{vent}) registered a marked decline in affective valence. Exercising below or at T_{vent} did not correspond with such a trend. They subsequently concluded that a physiological parameter such as T_{vent} appeared "to be the 'turning point' beyond which affective valence starts to decline" (2008, p. 146).

This turning point was based on the Dual Mode Model (Ekkekakis, 2003), which postulates that at T_{vent} physiological indices such as frequency and depth of respiration, and blood lactate accumulation are accentuated. Thus, this threshold might represent the point in exercise intensity which marks the transition from a cognition-dominant to an interoception-dominant mode of eliciting both affective and exertional responses (Hall, Ekkekakis, & Petruzzello, 2005). According to this model, affective and exertional responses associated with exercise performed at intensities close or below the T_{vent} involve primarily cortical pathways. However, at intensities beyond

T_{vent}, interoceptive afferent cues are relayed via more direct and faster routes, bypassing the cortex, to brain regions that are responsible for the elicitation of affective and exertional responses (Ekkekakis & Acevedo, 2006). Researchers have demonstrated that T_{vent} generally occurs at 79% $\dot{V}O_{2max}$ for physically active adults, while sedentary adults rarely reach or surpass 60% $\dot{V}O_{2peak}$. Nonetheless, the exercise intensities reported in previous research (Boutcher & Trenske, 1990; Elliot et al., 2004, 2005) were extrapolated from maximal heart rate, which has been criticised by physiologists as an unreliable method of exercise standardisation as it does not accurately reflect ventilatory responses (Katch et al., 1978). This inaccuracy renders it difficult to determine participants' exact ventilatory or lactate threshold.

A likelihood, given the nature of the protocol, is that at certain periods during the time trial, participants were working above their T_{vent}. The presentation of music, it would seem, was ineffective in influencing affective valence above this physiological threshold. However, if one adopts a similar perspective that was used to explain the findings of perceived exertion in the current study, it is evident that the presence of music did have considerable influence on the affective states of participants. It is plausible that the generation of higher levels of work output would lead to a greater degree of displeasure being experienced by participants (Ekkekakis et al., 2008). Yet, similar to the RPE findings, the level of displeasure expressed by participants in the current study did not significantly differ across conditions, possibly indicating that the presence of music attenuated further declines in affective valence associated with greater work output. Nonetheless, given the absence of cardiorespiratory measures, definite conclusions regarding the intensity at which participants were working at during the time trial cannot be drawn.

Researchers have nevertheless observed that music was capable of influencing affective valence even at high exercise intensities (Boutcher & Trenske, 1990; Elliot et al., 2004; 2005; Tenenbaum et al., 2004), although the authenticity of their findings requires clarification. The studies that have reported positive in-task affective valence at high workloads typically prescribed exercise intensities between 75-80% of maximal heart rate (e.g., Boutcher & Trenske, 1990; Elliot et al.). Such intensities are considered to rely upon aerobic pathways in some instances (Katch et al., 1978). Exercise physiologists have long regarded the prescription of exercise intensity via numerical percentages of aerobic capacity or maximal heart rate to be inaccurate as it does not account for the balance between aerobic and anaerobic metabolic processes (Wasserman et al., 2005). Therefore the proposition that music is capable of positively influencing affective valence at high exercise intensities only holds true if participants were working below T_{vent}.

Current findings indicate that even though participants reported a decline in affective valence as the time trial progressed, the presentation of music, specifically the introduction of music in the second half of the time trial, attenuated this decline to a greater degree than the other music conditions. It is presently unclear why this was the case. On one hand, if the mere presence of music was the main contributing factor to this attenuation effect, the participants should have exhibited at least some degree of attenuation for the decline in affective valence for each experimental condition when compared to the control trial. On the other, if the introduction and removal of music was responsible for preventing a considerable decline in affective valence, participants under M2 should have reported some comparable differences. Considering that there is scant empirical evidence to draw upon, and that extant theory does not explain the present findings, one can only make speculations.

Researchers have shown that running outdoors resulted in attention being directed more frequently to external stimuli such as the environmental cues, while running on a treadmill in a sterile laboratory setting made participants more aware of internal symptoms of fatigue (Harte & Eifert, 1995; LaCaille, Masters, & Heath, 2004) Moreover, it has also been observed that running outdoors elicits more positive moods when compared to running indoors, although it is unclear whether these effects were due to differences in attentional strategies or the aesthetics of the exercise environment (Harte & Eifert; LaCaille et al.). Nonetheless, musical accompaniment is widely implemented to encourage dissociation and thus combat the negative sensations associated with exercise fatigue (e.g., Crust & Clough, 2006; Elliot et al., 2005; Tenenbaum et al., 2004).

It should be noted that, because the attentional strategies of participants were not recorded in the present study, it is impossible to ascertain the types of attentional strategies adopted. Nevertheless, if the provision of pleasant external stimuli does influence one’s focus of attention, as was reported by Harte and Eifert (1995), and LaCaille et al. (2004), it is suggested that participants in the current study were likely to be focusing more internally during control, and externally during M1. Further, participants in M2 would adopt an external-to-internal focus of attention, while an internal-to-external attention focus would be adopted for M3. Towards the end of the time trial, it was expected that participants in all conditions would be focussed internally due to the predominance of physiological cues. Given these scenarios, affective valence would be expected to differ between the no-music and experimental conditions, but this was not observed. The fact that the decline in affective valence was only attenuated in M3, but not in M1 and M2, would suggest that there are other mediating factors involved, such as the specificity of music exposure. Indeed, the large effect size reported for the Condition x Distance interaction for in-task affective valence ($\eta_p^2 = .14$) indicates that a significant portion of the variance was accounted for by this particular music manipulation.

Considering the different attentional foci participants might adopt in each experimental condition, and the interactions that were reported, it is plausible that a switch in focus of attention, specifically from internal to external (M3), was responsible for attenuating the decline in affective valence. A switch in the opposite direction, from an external to internal focus of attention (i.e., M2), or a sole focus of attention, either internal (C) or external (M1), do not appear to have the same effect on participants' affective valence. The halfway mark of a 10-km time trial might be considered the point at which participants were becoming more acutely aware of the internal physiological cues resulting from accumulating fatigue (Lim et al., 2009; Tenenbaum & Connolly, 2008). The sudden introduction of an external stimulus such as music may have provided participants with an unexpected but welcome diversion that was aesthetically pleasing and strong enough to combat the accumulating fatigue of the ever-increasing physiological strain. This view is shared by Szabo et al. (1999), who contended that a change from slow- to fast-tempo music as participants approached 70% maxHRR could engender a temporary switch from an internal to an external focus of attention. Studies using similar methods of music presentation have reported positive outcomes, although these did not examine affective outcomes (e.g., Lucaccini 1968; Szabo et al.).

Such a proposition, however, would appear to contradict Harte and Eifert's (1995) findings, since participants in M1 did not report any changes in affective valence when compared to control. There is, however, a straightforward explanation: The provision of music allowed participants to cycle faster without experiencing further declines in affective valence associated with elevated work outputs. It is plausible that any music-induced enhancements in affective valence might have ameliorated the displeasure that might have resulted from the increase in workload.

Of course, these speculations assume that participants have minimal flexibility in the type of attentional focus they adopt throughout the duration of the task, but researchers have argued otherwise (see Lind, Welch, & Ekkekakis, 2009; Salmon, Hanneman, & Harwood, 2010, for a review). It is more plausible that individuals are more inclined to have a dominant attentional focus during a task, but are still able to exhibit both internal and external attentional foci, dependent on the situation, as shown in the current observations and past studies (e.g., Harte & Eifert, 1995; LaCaille et al., 2004). Another factor that could influence participants' attentional focus is task intensity. Hutchinson and Tenenbaum (2007) reported that task intensity mediated the attentional focus adopted by participants in a hand grip task and a stationary cycle ergometry task. Their findings indicated that attentional focus was mostly dissociative at low exercise intensities, and became progressively associative as the exercise intensity increased. At high exercise intensities, attentional focus is predominantly internal, as physiological cues occupy focal awareness. Nonetheless, Hutchinson and Tenenbaum's results may not be closely applicable to a self-paced task such as a cycling time trial, wherein task intensity is not fixed.

Current findings on subjective arousal would seem to indicate that participants were more aroused under the influence of music than without it. The observation that the timing of exposure mediated the rate of change in arousal only serves to reinforce this point. These results lend further support to existing literature in general musicology (North & Hargreaves, 1997), emotion (Sloboda & Juslin, 2001), and sport/exercise-related research (Karageorghis & Terry, 2009) that have documented music's potential to arouse. Interestingly, Bishop, Karageorghis, and Kinrade (2009) have reported that elevated levels of subjective arousal were associated with improved choice reaction time (CRT) performance, and their findings substantiate previous research suggesting the involvement of higher overall cortical activation in the prediction of subsequent CRT performance (Winterer et al., 1999). If this is indeed the case, it is plausible that the increase in work rate may be related to greater cortical activation as a result of higher levels of arousal.

Berlyne (1974) had proposed an inverted-U relationship between the preference for a musical stimulus and its arousal potential. According to this relationship, preference is greatest for music that possesses moderate arousal potential, and this decreases at low or high arousal potentials. Assuming that music preference may have an indirect effect on the amount of pleasure a participant experiences, a plausible explanation for the stability of affective valence reported by participants in M3 when compared to M1 is that the constant exposure to music led to over-arousal, causing a declinein preference for the music, and thus reducing the amount of pleasure participants might otherwise derive from music listening. Nonetheless, if this were the case, it could be argued that participants in M2 should experience higher levels of pleasure, since music in this condition theoretically possesses a similar arousal potential to the one used in M3, but results did not reflect this notion. Affective valence in the first half of the time trial across all conditions was identical, possibly indicating that the presence or absence of music in this segment was relatively inconsequential to pleasure ratings (see Figure 3.8). Nonetheless, the use of pleasure as an indicator of preference may not be the most appropriate; a separate measure for music preference should be included for a more accurate assessment. Moreover, according to the circumplex model, valence and arousal dimensions are orthogonal; thus a high level of arousal may not necessarily be associated with negative valence.

3.4.4 Limitations

There are a few limitations that may have influenced the results of the present study. Firstly, the track arrangement presented a problem. As detailed in the methods section, the order of tracks in the playlist was randomised for each participant across each experimental condition to maintain a degree of internal validity. This meant that each participant ended up listening to a different track at any given point in the time trial, and this was the case across conditions. Randomisation of the playlist in this manner presented a problem in terms of standardisation. For example, when participants were feeling more fatigued, the track that was being played would be different for Participant 1 when compared against participant 2. So if Participant 1's track was more motivational for him, while Participant 2 did not find his track particularly motivating, participant 1 would be more likely to perform better than participant 2, at least for the duration of that particular track. Moreover, this also poses an intra-participant problem whereby the order of tracks a participant is presented with differed under each experimental condition.

A possible solution to this unequal exposure might be to standardise the order of the tracks, in ascending order of tempi. Full tracks would be played for condition M1, while the playlist for M2 and M3 would contain shortened versions of the full playlist, but still retaining the same order of presentation as in M1. This idea has been successfully implemented in studies investigating the relationship between music tempi preference and heart rate, wherein excerpts of tracks were used (e.g., Karageorghis, Jones, & Low, 2006; Karageorghis et al., 2008; Karageorghis et al., 2011), and could possibly work for the current experimental protocol. Nonetheless, this brings about a different problem: Because of variations in trial times, some participants would end up listening to a greater or lesser number of tracks. This is proposed to be much less of a confound when contrasted against having each participant listen to a different piece of music across trials.

Another limitation pertains to the music selection process: Even though the music selection process followed the guidelines and recommendations of Karageorghis et al. (2006), there exists a possibility that the music tracks selected by the rating group were not aligned to the musical preferences of the experimental participants. Even though the population demographics of the rating panel matched that of the experimental sample, it does not mean that music deemed motivating by the raters would necessarily reflect the preferences of the experimental group, and could accordingly, have diminished the effects of music. It has been shown that preferences can differ between individuals even for the same piece of music (North & Hargreaves, 1998), and factors such as musical experience, context, and personality play a mediating role. In fact, music preference is largely dictated by the context one is in (North, Hargreaves, & Hargreaves, 2004). The rating panel only had to imagine the exercise situation, whereas experimental participants had to undergo the exercise protocol. There is a possibility that this mismatch of context might have influenced music preference. Participants' aesthetic response or preference for the music could have been recorded at the end of each trial to gauge whether this was indeed the case. Moreover, the hierarchical structure of musical factors in determining motivational quotient does not always hold true. For example, junior tennis players appeared to place greater emphasis on the extrinsic rather than the intrinsic properties of music (Bishop et al., 2007).

Self-selection of music by participants might be a viable option as it ensures the motivational qualities of music are optimised according to individual preference. In addition, by using such an approach, it would allow future researchers to look at the effects of music across samples with different demographics, as one of the restrictions on the proposed guidelines requires the demographics of the target population to be similar. Even though there is some evidence to suggest that the effects of music are more pronounced when it is individually chosen compared to one that was selected by experimenters (e.g., Nakamura, Pereira, Papini, Nakamura, & Kokubun, 2010; Smith & Widmer, 2004), no studies have yet compared the effects of self-selected music against music chosen via recommended guidelines, such as those proposed by Karageorghis et al. (1999, 2006). Future research covering this aspect would certainly provide clarification on this matter.

Given that participants’ cycling ability was relatively heterogeneous, present findings should not be generalised to specific sub-groups of the population such as elite cyclists or patients undergoing rehabilitation. The large reductions in race time may not be translatable to elite-level cyclists; such athletes are considered to be in peak physical condition, and accordingly, their margins for improvement may be relatively small (Atkinson, 2003). Certain patient groups, such as those undergoing cardiac rehabilitation, may wish to avoid the use of stimulative music; observations from the present study suggest it could lead to increased cardiovascular strain, which may not be ideal for someone recovering from heart-related disease.

3.4.5 Practical implications

The present findings appear to suggest that the application of music, and the manipulation of its exposure, could provide significant benefits to athletes, recreational exercisers, and even certain clinical populations engaged in physical rehabilitation. Although the use of music is prohibited in competition by most governing bodies of sport, athletes frequently use music in training and prior to an event. A carefully selected music programme that takes into consideration an athlete’s musical preferences could possibly lead the athlete to maximise effort exertion during training sessions, without suffering adverse psychological consequences (i.e., heightened displeasure associated with greater workloads). This would optimise the quality of training by potentially allowing athletes to train at near maximal capacity; training at high intensities has been reported to improve gross efficiency in trained cyclists (Hopker et al., 2009). Additionally, the manipulation of music exposure might assist athletes in regulating their work output. For example, in professional cycling, a higher than average power output is required to successfully ascend hills (Atkinson et al., 2004). The presentation of music in such instances could help condition cyclists to the physiological demands associated with the task, at least during training. For example, providing music accompaniment during parts of a time trial with hilly terrain might encourage athletes to achieve an optimal power output. Consequently, cyclists would be better prepared physiologically to tackle the ascent during the actual trial.

Although cycling time trials were used in the current study, it is probable that present observations are replicable in other forms of endurance-based events such as running, swimming, and rowing. There is evidence indicating that rowers produced superior performances when exposed to music when compared to a no-music control (e.g., Rendi et al., 2008). Similarly, runners listening to music have been found to report more positive effects compared to when they did not have music accompaniment (e.g., Nethery, 2002; Szmedra & Bacharach, 1998). Ostensibly, other modalities of exercise may also benefit from a differentiated music exposure approach.

A strong relationship between affective valence and exercise adherence has been proposed (Ekkekakis et al., 2008). It has long been considered that to maintain exercise behaviour, especially during the early stages of an exercise regime, the activity has to be deemed sufficiently pleasurable in order for the exerciser to select it over other pleasurable alternatives (Morgan, 1977). Accordingly, the presentation of music during the latter stages of exercise could attenuated the decline in affective valence and make the overall experience seem more pleasurable, and thus promote exercise adherence.

Clinical populations can also benefit from the use of music, in particular patients who are prescribed exercise programmes as interventions. For example, those undergoing physical rehabilitation would be able to achieve greater workloads in the presence of music, and as a result, improve their cardiovascular fitness in a shorter space of time. This would reduce the number of rehabilitation sessions that patients need to attend, saving time and money for both themselves and the health agencies. Another clinical group that could benefit from music are those suffering from Chronic Obstructive Pulmonary Disease (COPD). Sufferers of this condition have difficulty breathing as a result of permanent damage to the lungs and constricted airways (Institute for Quality and Efficiency in Health Care, 2011).

Patients with COPD are normally prescribed exercise to aid in pulmonary rehabilitation (Bauldoff, Hoffman, Zullo, & Sciurba, 2002), but often report dyspnea at exercise intensities that are well below what one would expect from their pulmonary function examination results, causing early cessation of exercise (Thornby, Haas, & Axen, 1995). Dyspnea has been defined as the “unpleasant awareness of laboured breathing” (Thornby et al., p. 1213). It has been suggested that one way to combat dyspnea is to reduce the perceptions of dyspnea from registering onto awareness (Thornby et al.). This idea bears similarities with Rejeski’s (1985) parallel processing model and Borg’s (1998) notion of perceived exertion. There is a corpus of work that has addressed the influence of music on COPD patients, but findings to date have been equivocal in nature (e.g., Bauldoff, Rittinger, Nelson, Doehrel, & Diaz, 2005; Leupoldt, Taube, Schubert-Heukeshoven, Magnussen, & Dahme, 2007; Pfister, Berrol, & Caplan, 1998). As with early music-related sport and exercise research (e.g., Boutcher & Trenske, 1990; Copeland & Franks, 1991; Pearce, 1981), the selection of music in such studies was often made arbitrarily by researchers. Accordingly there is a high possibility that the use of more carefully selected music would have yielded more consistent and positive outcomes.

Depending on the outcomes one is trying to achieve (i.e., performance or enjoyment), the use of appropriately selected music and its careful manipulation can assist greatly in the attainment of those outcomes. If enhanced performance is the goal, the presence of music for the entire duration of the task is likely to be most beneficial. Results from the current study suggest that music presented for the entire distance of a 10-km cycling time trial enabled participants to record race times that were on average, 44 s faster when compared to cycling without music accompaniment.

Nevertheless, participants appeared to experience less displeasure only when they were exposed to music in the last 5 km of the time trial, while the other music conditions had no such effect. Thus if one’s goal is the greater enjoyment of an activity, the presentation of music in the latter half of the task should be recommended instead.

3.4.6 Future directions

Current findings suggest that the single-blinded application of asynchronous music and its manipulation can improve overall performance in a 10-km cycle ergometer time trial without concomitant increases in perceived effort or negative affective valence. Nonetheless, future researchers might wish to consider informing participants of the intervention they are about to be administered. Such a suggestion might be deemed to pose a threat to internal validity; it has been argued that providing foreknowledge of the intervention would create possible expectancy effects (Karageorghis & Priest, 2011a, 2011b). Nonetheless, it is challenging to completely blind participants to an auditory stimulus (Lim et al., 2009); indeed, this is almost a contradiction in terms. A potential solution is to inform participants about the music condition they are to be exposed to, with no additional information pertaining to what experimenters expect to happen. Accordingly the expectancy effects associated with foreknowledge would be largely controlled for and any changes in dependent variables can be attributed to the music manipulation with greater certainty. In most instances, music accompaniment is a conscious decision made by the individual. Therefore one could question the wisdom of conducting music-related research whereby participants are blinded to the auditory stimulus. However, many would argue that the norm in empirical research is to first study a phenomenon under conditions of high internal validity before moving on to protocols that hold greater external validity. Nonetheless, there is conclusive evidence documenting the benefits of music in tightly controlled laboratory experiments (e.g, Crust & Clough, 2006; Elliot et al., 2005; 2005; Hutchinson et al., 2010; Waterhouse et al., 2010). This has only transpired in recent research; early works were largely inconclusive (see Karageorghis & Terry, 1997, for a review). Accordingly, it is timely to investigate if these laboratory-based findings can be replicated in more realistic and externally-valid situations (Karageorghis, 2008).

Although similar research has been conducted in the past (e.g., Atkinson et al., 2004; Lim et al., 2009), these studies were plagued by notable limitations, such as a small sample size and a haphazard music selection process. Accordingly, there is a need to validate these findings while ensuring limitations are accounted for. It is quite possible that more appropriately chosen music that is tailored to the preferences of participants will engender more positive responses in a cycling time trial, as was the case in the present study. In addition, Lim et al. proposed that participants in their study pre-planned an appropriate cycling strategy based on the information provided to them. However, this proposition was not corroborated as participants were not required to provide details of their cycling strategy. Future researchers might want to consider the use of qualitative methods of inquiry to gather more subjective information that cannot be obtained through conventional quantitative approaches. An interview, for example, would allow researchers to gain insight into participants’ thoughts on completing a 10-km cycling time trial under different permutations of music exposure, and how prior knowledge of such exposure may influence their racing strategy.

Researchers may also seek to investigate other populations, such as professional athletes. Current observations indicate that there is at least a 27 s reduction in time spent completing a 10-km cycle ergometer time trial associated with music accompaniment. In professional cycling events, such a difference can decide if one secures a medal or finishes in 4th place. Thus it would be interesting to see if present findings are replicable in an elite sample. Gender difference is another area worthy of future investigation; females are likely to respond more positively to current music manipulations, given their greater exposure to dance and music-related activities from an early age (Shen, Chen, Scrabis, & Tolley, 2003). It would also be worth investigating if the effects of differentiated music exposure are specific to cycling, or if it is replicable in different exercise modalities such as running and rowing. Tentative evidence from typical music-studies employing such modalities (e.g., Elliot et al., 2004; Rendi et al., 2008) would suggest that there is a high possibility that currents results are generalisable to other modes of activity.

3.4.7 Conclusion

Participants exposed to asynchronous music were generally faster than when they heard no music during a 10-km cycling time trial. These faster times were attributed to a combination of increased speed, power output, and cadence generated under exposure to music. Further, mean heart rate was significantly higher for M1 and M3 compared to control, but this increase in physiological strain did not result in a corresponding change in effort sense, suggesting that cycling to asynchronous music enabled participants to achieve greater physical performance without greater conscious effort. Pleasure and arousal were also affected by the application of asynchronous music, although the effects on valence seem to only manifest when music was presented in the second half of the TT. Subjective arousal followed a similar pattern to that of mean heart rate, and it suggested that increases in arousal led to greater cortical activation, which positively affected performance (cf. Berlyne, 1974; Bishop et al., 2009). Several limitations inherent to the current study were identified, mainly concerning the presentation and order of the playlist.

The present findings indicate that the benefits of listening to asynchronous music are not only observed in laboratory-based exercise tasks (e.g., Crust & Clough, 2006; Elliot et al., 2004; 2005) but are equally applicable to externally valid self-paced exercise protocols such as a 10-km cycling time trial. More important, the introduction of music midway through an exercise bout attenuated the decline in affective valence far more effectively than the other music conditions. The present findings may have considerable implications for athletes in training, and in particular, exercise adherence. In addition, these findings would also be useful to clinical practitioners involved in physical therapy or prescribing exercise as an adjunct treatment. The judicious use of music might allow patients to achieve greater workloads without a corresponding increase in perception of effort and negative affective valence. These factors could significantly improve an individual’s adherence to an exercise programme, and provide health practitioners with a viable and effective tool in enhancing exercise adherence and combating rising levels of obesity.

Chapter 4: Effects of Differentiated Music Exposure and Knowledge of Intervention on a 10-km Cycling Time Trial

4.1 Introduction

Given that music has been widely applied in a variety of real life settings, a shift in emphasis from traditional laboratory-type research to more externally valid protocols is required. While it is evident that music can engender numerous benefits under laboratory conditions, it is unclear if these benefits are manifested in tasks that are more representative of regular sporting events. Observations from the previous study in this thesis and that of past research (e.g., Atkinson et al., 2004; Ferguson et al., 1994; Lim et al., 2009; Rendi et al., 2008) do indicate that listening to appropriately selected music can enhance physical performance in a number of sports-related activities. Moreover, the psychological and psychophysical effects of music in such sports-related activities seem to manifest differently when compared to laboratory-based exercise protocols. Indeed, Lim et al. (2009) proposed that in the absence of kinematic efficiency, improvements in physical performance would negate any significant gains in terms of psychological and psychophysical responses. In such instances, music appears to operate by minimising the perceptions of exertion and displeasure that would normally be associated with an increased work output (Tenenbaum, 2001). Nonetheless, there is a dearth of empirical research using experimental tasks that reflect the realities of sport.

The manipulation of music exposure is another aspect that has received scant attention, even though it is not a novel idea and has been investigated as early as the 1960s. Lucaccini (1968) examined how presenting music in short intervals can enhance performance during a vigilance task. By interspersing instrumental music with 5-15 s intervals, participants were able to improve their performance compared to listening to white noise in a series of stimulus detection tasks. In a sport and exercise context, a few researchers have (e.g., Crust, 2004a; Lim et al., 2009; Szabo et al., 1999) have manipulated music in a similar manner, but such studies account for a minute portion of the total music-related research in this domain.

More recently, Lim et al. (2009) investigated the effects of segmented music exposure on a 10-km cycling time trial. Participants were presented with three conditions: No-music control, music for the first 5 km, and music for the last 5 km. They were informed of the conditions prior to the start of each trial. Although no significant main effects were observed for any performance variables across the three conditions, there was a significant Condition x Distance interaction for speed. The speed profile of participants cycling with music for the last 5 km was different compared to when they were not provided with music or when they had music for the first 5 km only. Specifically, participants were generating greater speeds in the first 5 km of the time trial when presented with music for the last 5 km compared to the other two conditions. Interestingly, the increase in speed came at a time where there was no exposure to music, indicating that there were other factors involved.

4.1.1. Central Governor Model and Pacing

Adopting the Central Governor Model of fatigue perspective (Noakes et al., 2005), Lim and colleagues proposed that participants could have used prior knowledge of the external environment to “pre-plan” their racing strategies. These strategies would be planned in a manner that allowed participants to complete the time trial without severe homeostatic disruption and at the same time optimise their performance outcomes. Accordingly, when presented with music for only the second half of the cycling task, participants may have decided to cycle faster for the first 5 km of the time trial, with the foreknowledge that there would be musical accompaniment during the latter stages serving as a motivational stimulus to carry them through. This notion of prior planning is given further weight by the results from the previous study in this thesis. When participants were blinded to the conditions, speed profiles over a 10-km time trial were distinctly different when compared to those reported by Lim et al.; greater velocities were only observed during periods of music exposure. Therefore, providing prior knowledge of the music intervention appears to have influenced participants' cycling strategies.

Researchers have proposed that individuals develop certain pacing strategies to complete a given exercise task when provided with knowledge of the endpoint or time to be covered for that task (St Gibson et al., 2006). This information allows the brain to calculate the necessary physiological requirements needed to finish the task without severe disruption to homeostatic functioning. Ulmer (1996) coined the term *teleoanticipation* to describe the process wherein the brain considers the knowledge of the endpoint as a reference to create a particular algorithm for the exercise task, and uses it to regulate power output during the task itself. For example, if the algorithm indicated that current work output was at a level that could not be maintained without premature fatigue, efferent neural commands would be altered to regulate output, and the related metabolic rate, to a more manageable level as determined by the algorithm. Vice versa, if work output was too low, efferent neural commands would be changed to increase physical effort, and the associated metabolic rate would also increase as a result (St Clair Gibson et al.).

The brain also takes into consideration other factors in the computation of an appropriate pacing algorithm. Prevailing environmental conditions, metabolic reserves, and health status are some examples that can influence the formulation of the pacing strategy. Therefore, the provision of a stimulus such as music and the knowledge of it could change the external environment and possibly alter the pacing algorithm. Moreover, if teleoanticipation does regulate work output during the exercise bout, manipulation of the external environment during the course of the activity should cause changes in the pacing strategy. Although some support for this proposition was reported by Lim et al. (2009), further research is required to validate their observations. It would also be of interest to investigate if the formulation of a particular pacing strategy is a conscious or subconscious process. Lim et al. have suggested that the use of qualitative methods of inquiry, such as interviews, could elucidate information from participants that might not otherwise be reported via quantitative means.

4.1.2 Purpose of the Present Study

The present research attempts to build upon the findings reported in Study 1 and that of Lim et al. (2009). The design of the present study is a hybrid of the two aforementioned studies, with three key differences: (a) participants were given prior knowledge of the intervention in order to ascertain whether this information altered the overall cycling strategy, (b) semi-structured interviews were conducted to determine if changes in cycling strategy were carried out consciously or subconsciously, and (c) the order of the playlist was standardised for conditions with musical accompaniment to ensure that participants were presented with tracks that were arranged in the same sequence.

Based on previous observations, it was hypothesised that participants cycling under music exposure would achieve better performances compared to cycling without music. In addition, racing strategies were expected to differ from the previous study in this thesis due to participants being given advance knowledge of the interventions. Specifically, based on previous research (Lim et al., 2009), the present author proposed that a fast-start strategy would be used when participants were told music will be presented in the second half of the trial, whereas participants' cycling strategy for music presented in the first 5 km would be similar to the control condition. It was unclear what sort of cycling strategy would be used when music is played for the entire distance, as this was not examined in Lim et al.'s work (2009). Nonetheless, results from Chapter 3 of this thesis seemed to indicate that participants generated consistently higher speeds in such conditions. Accordingly, a similar speed profile to that seen in Chapter 3 data was expected in the current study.

In terms of psychological and psychophysical responses, it was hypothesised that any differences would be dependent on the outcome of the performance under each trial condition. No changes were expected for in-task affective valence and RPE if superior performance levels were recorded.

Moreover, it was anticipated that superior performance would be accompanied by increases in heart rate and subjective arousal. The reverse was predicted if there were no differences in performance: Heart rate and arousal would not differ from the control condition, although positive changes for in-task affective valence and reductions in RPE would be expected.

4.2 Methods

4.2.1 Music Selection

The same seven tracks used in the previous study of this thesis were selected for the present experiment. This decision was taken to ensure the motivational qualities of music were standardised and would not be an issue when comparing current findings to those reported in the previous study. Out of the seven tracks, one was omitted (*AYO Technology* by 50 Cent) as the majority of participants from the previous study had expressed their dislike for this particular music selection.

Musical tracks were sequenced into a playlist with an ascending order of tempi (see Karageorghis et al., 2011). Full tracks were played when music was presented for the entire distance (Appendix E), while a truncated version of the full playlist, containing at least a verse and chorus of each track was used for the trials with segmented music exposure. More importantly, the shortened playlist retained the same order of track presentation as the full playlist. This approach ensured that a consistent order of tracks was played across each trial. Some may argue that with such an approach, there is a possibility that the number of tracks participants were exposed to would vary according to race times (i.e., fewer tracks heard for faster times).

Nevertheless, the impact associated with this approach is considered by the present author to be less significant and less of a confounding factor than asking participants to listen to different selections across trials, a limitation that was identified in Study 1 of the present programme of research.

4.2.2 Experimental Investigation

4.2.2.1 Power analysis. A power analysis was conducted to establish appropriate sample size with alpha set at .05 and power at .8 to protect beta at four times the level of alpha (Cohen, 1988). A conservative estimate of .5 was selected for the inter-correlation between repeated measures, while the non-sphericity correction entered was 1. Using an estimated moderate effect size for the effects of asynchronous music compared to a no-music control ($f = 0.25$), it was estimated that a total of 24 participants would be required.

4.2.2.2 Participant Characteristics. Participants comprised 24 males (M_{age} = 19.8 years, M_{weight} = 77.0 kg, M_{height} = 179.4 cm) from the body of sport sciences undergraduates at Brunel University. A male-only sample was chosen owing to the possible effects of the menstrual cycle on performance/affective responses (see Reilly, Atkinson, & Waterhouse, 1996) that would have made testing impractical; one would have to wait to test females at a similar stage of their menstrual cycle in between trials to yield meaningful findings. There is also the possibility that the internal validity of the study would be compromised; mood states have been found to vary through the course of the menstrual cycle, and by logical extension, the effects of music on affect may be compromised and present a potential confound (Reilly et al.). Further, given that the researcher is male, there could be potential ethical issues with regards to enquiring about a female participants’ menstrual cycle; this could be deemed to be highly inappropriate.

Participants who completed all sessions were given £10 as reimbursement for their travel expenses. They were briefed on the nature of the study, provided written consent (Appendix A), and filled out a health questionnaire (Appendix D) before commencing the experiment. All procedures were approved by the University’s Research Ethics Committee.

4.2.2.3 Familiarisation and experimental design. Participants were required to undergo one familiarisation session. Pilot work by Atkinson et al. (2004) indicated that this was likely to reduce systematic and random errors associated with a 10-km time trial distance. Further, research by Altareki et al. (2006) indicated that at least one familiarisation trial was required to reduce the possible influence of learning effects with the use of the CompuTrainer ergometer (RacerMate, UK) for a time trial protocol. Although the cycle ergometer used in the current study was the Velotron, the results obtained by Altareki et al. were applicable as the two ergometers are manufactured by the same company and serve similar purposes. This session also served to acquaint participants with the various psychological and psychophysical scales that were to be administered during the experimental phase.

Participants underwent a total of four experimental trials (see Figure 3.2): Control condition with no music (C); music throughout the trial (M1); music introduced from 0-5 km (M2); and music introduced from 5-10 km (M3). The trials were administered in a counterbalanced (between trials) order to guard against potential familiarisation/learning effects, and tests were separated by at least 48 hr to allow for adequate recovery. There was a 5 min warm-up prior to the commencement of each trial, as well as a 5 min cool-down immediately after completion. Participants were told of the impending music intervention during the warm-up phase of every trial.

Participants were requested to adhere to identical patterns of activity (no other vigorous physical activity) and diet 24 hours prior to the trial, and to refrain from eating 2 hr prior to testing. Each participant engaged in the trial individually in the presence of a same-sex researcher (cf. Anshel & Marisi, 1978). Music intensity was standardised at 85 dBA by use of a decibel meter (AZ 8928; AZ Instrument Corporation, Taichung City, Taiwan); this level is within the safe limits from an audiological perspective (see Alessio & Hutchinson, 1991). The playlist was stored in a computer laptop and delivered via speakers located at the rear of the laboratory.

4.2.3 Measures

4.2.3.1 Performance variables. Overall race time was automatically recorded by the Velotron Software at the end of every time trial. Speed, power output, and cadence were recorded continuously throughout the entire time trial by the software provided with the Velotron. These performance variables were subsequently averaged out into two halves – 1st half (0-5 km) and 2nd half (5-10 km) – for data analysis.

4.2.3.2 Ratings of perceived exertion and heart rate. Participants' perception of effort was determined using Borg's Category Ratio 10 scale (CR10; Borg, 1998). The scale has a range of 0 (*nothing at all*) to 10 (*very very hard*), proceeded by a dot denoting maximal exertion. Validity of the scale has been demonstrated in terms of its correlations with common physiological indices such as heart rate and $\dot{V}O_2$ (r = .80 to .95; Borg). High intratest (r = .93) and retest (r = .83 to .94) reliability have also been reported (Borg).

Participants' heart rates were measured using a chest strap and a heart rate monitor wristwatch (Polar Accurex Plus; Polar, Kempele, Finland). Both heart rate and RPE were measured at four different distance intervals during the time trial: 2.5 km, 5 km, 7.5 km, and 10 km. These distance points were chosen to maintain consistency with previous research that was similar in design (Atkinson et al., 2004; Lim et al., 2009), and thus to facilitate comparison.

4.2.3.3 Affective valence and arousal. Affective valence was assessed using Rejeski's (1985) Feeling Scale (FS), an 11-point single-item measure, with a scale ranging from -5 to +5. Descriptive markers are provided at zero (Neutral), and at all odd integers, ranging from "Very Bad" (-5) to "Very Good" (+5). The FS has shown correlations in the range .51-.88 with the valence scale of the Self-assessment Manikin (SAM; Lang, 1980), and in the range .41-.59 with the valence scale of the Affect Grid (AG; Russell, Weiss, & Mendelsohn, 1989). According to Ekkekakis and Petruzzello (2002), the FS is a suitable and valid in-task affect measurement instrument, particularly because it limits respondent overload.

Arousal was measured using the Felt Arousal Scale (FAS) of the Telic State Measure (Svebak & Murgatroyd, 1985). It is a six-point, single-item measure with a scale from 1 to 6. Anchors are provided at 1 (Low Arousal) and 6 (High Arousal). The FAS has exhibited correlations between .45 and

.70 with the arousal scale of the SAM and .47 to .65 with the arousal scale of the AG. In-task affective valence and arousal were measured at four distance intervals during the time trial: 0.5 km, 4.5 km, 5.5 km, and 9.5 km. These distance points were chosen in order to examine the impact of music introduction and removal.

4.2.3.4 Pre- and post-task affective valence and arousal. Thayer's (1996) Activation Deactivation Adjective Check List (AD ACL) was administered prior to commencement and at the end of trials to measure pleasure and activation. The AD ACL is a 20-item questionnaire that taps the bipolar dimensions of Energetic Arousal (EA) and Tense Arousal (TA), with each dimension comprising 10 items. Energy to Tiredness makes up the range for the dimension of EA, and Tension to Calmness for the dimension of TA. Comprehensive data on the validity and reliability of the AD ACL have been reported by Thayer (1978, 1986), as well as Ekkekakis, Hall, and Petruzzello (2005). For example, the correlation between Energy and Tiredness was -.58, while the correlation between Tension and Calmness was -.50. A range between -.22 and .34 was observed for the other factor correlations (Thayer, 1978). The following reliability estimates for each dimension were also reported by Thayer (1978) in a test-retest study: Energy = .89; Tension = .89; Calmness = .79; Tiredness = .89. In addition, Ekkekakis et al. have shown that the structure of the AD ACL corresponds to a circumplex model when used in a physical activity context. It appears that the items related to Energy tap the high-activation pleasure quadrant, items related to Tension tap the high-activation displeasure quadrant, items related to Tiredness tap the low-activation displeasure quadrant, and items related to Calmness tap the low-activation pleasure quadrant.

4.2.3.5 Music preference. Preference for the music programme was recorded at the end of experimental condition by asking participants to respond to the following question: “Rate your preference for the music programme you have just heard”. Responses were made by indicating a number on a 10-point scale anchored by 1 (I do not like it at all) and 10 (I like it very much).

4.2.3.6 Motivational qualities of music. Participants chosen to partake in the interview process were required to assess the motivational qualities of the current music tracks using the BMRI-2 (Appendix B). The BMRI-2 is a single-factor, 6-item rating scale that possesses stronger psychometric properties to the original BMRI (Karageorghis et al., 1999). Responses are made on a 7-point Likert scale anchored by 1 (strongly disagree) and 7 (strongly agree). The initial item pool was established through in-depth interviews, and assessed using confirmatory factor analyses. A mean alpha coefficient of .89 was reported for the single factor (Karageorghis et al., 2006). Several independent researchers have utilised the BMRI-2 in their empirical studies (e.g., Crust & Clough, 2006; Hutchinson et al., 2010), suggesting that it is a valid and reliable tool for assessing the motivational qualities of music in sport and exercise.

4.2.4 Qualitative Inquiry

Eight participants were randomly selected to participate in a short, semi-structured interview at the end of experiment, in order to elucidate the thought processes, feelings, and behaviours associated with completing a 10-

km time trial under the different music manipulations. The interviews were conducted in the main testing laboratory for convenience and accessibility. Recordings of each interview were made using a Dictaphone, and the duration of interviews averaged 10.3 min (*SD* = 3.1 min).

4.2.4.1 Interview guide. Participants responded to a total of 10 open-ended questions related to three broad themes (Appendix F): (a) cycling strategy, (b) consequences of music manipulation, and (c) music preferences. Lim and colleagues (2009) previously proposed that the nature of music exposure dictated the type of racing strategy a participant adopted. Yet it was unclear to them if the adoption of a particular strategy was a conscious or subconscious process. Moreover, it was also important to gain an insight into how participants viewed the current presentation of music; they may prefer music to be presented in an entirely different manner. A final question which allowed participants to voice their comments was also included to capture any thoughts that may not have been elucidated by the preceding questions.

As recommended by Strean (1998), elaborative probes and follow-up questions were incorporated into the interview process to encourage participants to expand upon their answers and to garner a more detailed understanding of their responses. At the start of each interview, it was emphasised to the participant that there were no right or wrong answers, and they were free to speak their mind. At the end of the interviews, participants were requested to listen to excerpts of the seven musical tracks and rate them using the BMRI-2. This procedure was undertaken to determine if there were any discrepancies between the initial music rating panel members and the experimental participants. Once the rating process was completed, participants were debriefed by the investigator as to the purpose of the research.

The interview process was conducted by the present author, who possessed adequate knowledge of the research topic. Further, as a long-distance runner, He had prior experience of similar endurance-based activities, and frequently used music as part of my own training regime. He is also a certified fitness instructor, and was involved in the delivery of music programmes in a gymnasium and for cardiac rehabilitation sessions. Pilot interviews were also conducted with a researcher who had received training in social scientific research methods; appropriate feedback and recommendations were provided by this social scientist that aided the present author in further developing his interviewing skills.

4.2.5 Data Analysis

4.2.5.1 Quantitative data. The four distance points assessed for heart rate, RPE, affective valence, and arousal were averaged out to give two scores each; 1st half (0-5 km) and 2nd half (5-10 km). This was done to provide a more parsimonious means of analysing and reporting the data. Moreover, it allowed for a standardised form of comparison to be made with the results presented in Chapter 3.

Raw data were screened for univariate outliers using standardised scores ($-3.29 \leq z \geq 3.29$), and where relevant, the Mahalanobis distance method with $p < .001$ was used to identify multivariate outliers (Tabachnick & Fidell, 2007, p. 73). These procedures were carried out for each separate analysis and for each cell within each analysis. Further, skewness and kurtosis were examined in each cell of the analysis to check for deviations from normality (Std. Skew/Kurt. ≥ 1.96; Vincent, 2005, p. 89). Tests were also carried out to ensure the data met the relevant parametric assumptions. A one-way repeated-measures ANOVA was applied to the overall race time and music preference, while all other variables were analysed using a two-factor 4 (Condition) x 2 (Distance), within-subjects ANOVA. Univariate tests were corrected for sphericity violations where necessary, using Greenhouse-Geisser adjusted *F* values. Analyses were performed using SPSS for Windows Version 15.0 (SPSS Inc., Chicago, IL).

4.2.5.2 Qualitative data. The present author transcribed the interviews verbatim, and transcripts were read over in their entirety several times in order to familiarise oneself with the data. A content analysis was conducted using an inductive approach, allowing themes and concepts to emerge from the data (Strauss & Corbin, 1998). Transcripts were broken down into raw data themes or basic units, which were quotes that clearly identify a subjective experience (Biddle, Markland, Gilbourne, Chatzisarantis, & Sparkes, 2001). These quotes were then subjected to a clustering procedure (Scanlan, Ravizza, & Stein, 1989). This process involves comparing and contrasting each quote against all other quotes, uniting or separating quotes based on similarities or differences in meaning, and grouping them into emergent themes. This process of comparing and contrasting was continued to identify new higher-order themes and was only stopped when no further themes could be identified.

Transcripts were uploaded onto NVivo software Version 8 (QSR International Inc., Cambridge, MA), which served as a platform to analyse, code, and group the data simultaneously. The data were coded at the point of emergence rather than at the end of the transcript, and were subjected to continual adjustments and cross-referencing. This was considered a reflexive process, which has been highlighted by Brody (1992) as an integral aspect of qualitative data analysis. Further, in an attempt to refine and challenge my coding and grouping of themes, a researcher who possesses considerable knowledge in the subject area and in qualitative inquiry was included in the data analysis process as a form of external audit (see Lincoln & Guba, 1985). This researcher critically challenged and questioned some of the codings and the relevance of certain themes. Numerous discussions took place in order to reconcile any differences in opinions, and changes were made where necessary. Consensual validation was achieved when both the researcher and the present author arrived at an agreement regarding the final coding of the data. Illustrative quotes from the interviews were provided to allow readers to judge the trustworthiness of the data and to form opinions for themselves (Rees & Hardy, 2000).

4.3 Results

Although 24 participants were recruited for study, one participant withdrew after the first two sessions due to injury. In this section, performance variables are presented first, followed by psychophysical and psychological variables. No univariate outliers were identified for any variable during the data screening process, but violations of normality were identified for power output, cadence, heart rate, pre and post task affective valence, and the two dimensions of EA and TA. Standard skewness and kurtosis scores, and descriptive statistics for each dependent variable are presented in Table 4.1 and Table 4.2 respectively. The details pertaining to each analysis will be covered in the subsequent subsections.

4.3.1 Time to Completion

Data screening revealed no univariate outliers, and there were no violations of normality in tests of standard skewness and kurtosis (see Table 4.1). Given that the data met the relevant parametric assumptions, ANOVA was retained as the test of significance. Mauchly's test of sphericity revealed no violation for the assumption of sphericity ($W = .695$, $\varepsilon = .790$, $p = .183$).

The condition effect was not significant, $F(3, 66) = 1.17$, $p = .329$, $\eta_p^2 = .05$, and accounted for 5% of the variance. Although no significant differences were observed, participants cycling with music generally completed the time trial faster when compared to cycling without music. The differences were also in the expected direction; M1 was associated with the fastest times, followed by M2 and M3, and finally control (see Table 4.2).

4.3.2 Speed

Data screening revealed no univariate outliers, and there were no violations of normality evident in tests of standard skewness and kurtosis (see Table 4.1). Given that the data met the relevant parametric assumptions, ANOVA was retained as the test of significance. Mauchly's test of sphericity revealed no violations for the assumption of sphericity for the Condition x Distance interaction ($W = .741$, $\varepsilon = .863$, $p = .288$), or the condition main effect ($W = .772$, $\varepsilon = .841$, $p = .373$).

Table 4.1

Standard Skewness and Kurtosis for each Dependent Variable, under Each Condition, across Both Halves of the Time Trial

Variable	Condition	Distance	Std. Skew.	Std. Kurt.
Race Time	Control		1.17	.71
	M1		2.01	1.78
	M2		-.49	-1.18
	M3		-.23	-.73
Speed	Control	1st half	0.11	-0.90
		2nd half	-1.12	0.90
	M1	1st half	-1.17	-0.12
		2nd half	-1.15	1.09
	M2	1st half	0.54	-1.09
		2nd half	-0.45	-0.42
	M3	1st half	1.18	-0.96
		2nd half	-0.35	-0.66
Power Output	Control	1st half	0.73	-1.02
		2nd half	-0.29	0.76
	M1	1st half	-0.38	-0.41
		2nd half	-0.29	0.86
	M2	1st half	0.87	-1.12
		2nd half	-0.12	-0.30
	M3	1st half	1.71	-0.61

(table continues)

Table 4.1 (continued)

		2nd half	-0.08	-0.82
Cadence	Control	1st half	1.66	-0.03
		2nd half	0.46	-0.64
	M1	1st half	-0.23	-0.51
		2nd half	-0.86	0.36
	M2	1st half	0.31	-0.68
		2nd half	-0.15	0.44
	M3	1st half	0.21	-1.16
		2nd half	0.64	-0.83
Heart Rate	Control	1st half	-.64	.72
		2nd half	-1.95	1.23
	M1	1st half	-2.11*	1.16*
		2nd half	-3.55***	3.91***
	M2	1st half	-.47	-1.04
		2nd half	-1.39	-.70
	M3	1st half	-.10	-.57
		2nd half	-.78	-.95
RPE	Control	1st half	.37	-.10
		2nd half	-1.77	2.15
	M1	1st half	.69	-1.07
		2nd half	-.74	.51
	M2	1st half	.62	.18

(table continues)

Table 4.1 (continued)

		2nd half	-1.13	-.38
	M3	1st half	.79	.88
		2nd half	.05	-.04
In-task Valence	Control	1st half	.42	.25
		2nd half	.67	-1.08
	M1	1st half	-.86	-.90
		2nd half	-1.64	-.50
	M2	1st half	-.32	-.63
		2nd half	-.72	-1.38
	M3	1st half	-1.26	-.85
		2nd half	-.91	-.90
In-task Arousal	Control	1st half	-.42	-.83
		2nd half	.11	-.93
	M1	1st half	.72	-1.00
		2nd half	.24	-.76
	M2	1st half	-.87	-.72
		2nd half	-.83	-.96
	M3	1st half	-.33	.54
		2nd half	-.46	-.89
Energetic Arousal	Control	Pre-task	-.69	-.74
		Post-task	-1.99	.86
	M1	Pre-task	-1.83	1.70

(table continues)

Table 4.1 (continued)

		Post-task	-2.56*	2.45*
	M2	Pre-task	.29	-.85
		Post-task	-.11	-1.29
	M3	Pre-task	-.32	-.92
		Post-task	-1.25	.45
Tense Arousal	Control	Pre-task	1.99	.48
		Post-task	.97	-.49
	M1	Pre-task	-.82	.66
		Post-task	1.41	.65
	M2	Pre-task	-.55	-.03
		Post-task	.33	.24
	M3	Pre-task	-.75	-1.18
		Post-task	-.49	.05
Music Preference	M1		-.64	-.54
	M2		-.80	-.73
	M3		-.55	-.43

* *p* < 1.96, ** *p* < 2.58, *** *p* < 3.29.

Table 4.2

Overall Condition Means (SD) and Main Effects for all Dependent Variables

Variables		*M*	*SD*	*F*(3, 69)	Source of diff.
Time to Completion (s)	Control	1199.91	107.51	1.17	
	M1	1175.97	92.54		
	M2	1181.43	78.77		
	M3	1185.35	97.14		
Speed (km/h)	Control	30.38	2.62	1.06	
	M1	30.92	2.26		
	M2	30.73	2.06		
	M3	30.69	2.54		
Power Output (W)	Control	161.89	34.21	.91	
	M1	168.38	29.74		
	M2	166.17	27.80		
	M3	165.90	34.74		
Cadence (rpm)	Control	88.77	8.32	2.61	
	M1	86.76	7.51		
	M2	86.49	9.58		
	M3	85.02	8.31		
Heart Rate (bpm)	Control	165.00	15.21	.61	
	M1	167.51	15.87		
	M2	165.90	13.50		
	M3	166.04	14.45		

(table continues)

Table 4.2 (continued)

RPE	Control	6.30	1.40	4.80**	M3 < M2, Control
	M1	6.11	1.40		
	M2	6.35	1.52		
	M3	5.81	1.39		
In-task Valence	Control	1.15	1.46	3.53*	M3 > Control
	M1	1.73	1.56		
	M2	1.20	1.39		
	M3	1.71	1.41		
In-task Arousal	Control	3.95	0.92	1.45	
	M1	4.20	0.72		
	M2	3.95	0.92		
	M3	3.99	0.90		
Energetic Arousal	Control	29.13	4.15	1.57	
	M1	30.72	4.84		
	M2	30.74	3.20		
	M3	30.13	5.11		
Tense Arousal	Control	25.07	4.82	1.32	
	M1	25.17	3.31		
	M2	25.59	4.06		
	M3	24.24	2.77		

(*table continues*)

Table 4.2 (continued)

Music Preference	M1	6.57	1.46	
	M2	6.33	1.33	.99
	M3	6.41	1.37	

Note. Bonferroni adjustments made for multiple comparisons.

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

4.3.2.1 Condition x Distance interaction. There was no significant Condition x Distance interaction, $F(3, 66) = 1.67$, $p = .181$, $\eta_p^2 = .08$, although the manipulation of these independent variables accounted for 8% of the variance, representing a moderate effect. The introduction and removal of the musical stimulus at different distance intervals appeared to influence the speeds at which participants chose to cycle. In M2, the removal of music in the second half of the 10-km time trial resulted in decreased speeds, while the introduction of music in M3 for the second half led participants to achieve higher speeds when compared to the first half (see Figure 4.1). Nonetheless, these differences did not reach significance.

4.3.2.2 Condition main effect. There was no significant main effect for condition, $F(3, 66) = 1.06$, $p = .372$, $\eta_p^2 = .05$, with this independent variable manipulation accounting for 5% of the variance. Cycling speeds were, on average, similar across conditions, although participants performed marginally better under the influence of music (see Table 4.2).

4.3.2.3 Distance main effect. There was no significant main effect for distance, $F(1, 22) = 3.13$, $p = .091$, $\eta_p^2 = .12$, although this independent variable manipulation accounting for 12% of the variance, representing a moderate-to-large effect. Minimal changes in speed were observed from the first to the second half of the time trial (see Figure 4.1).

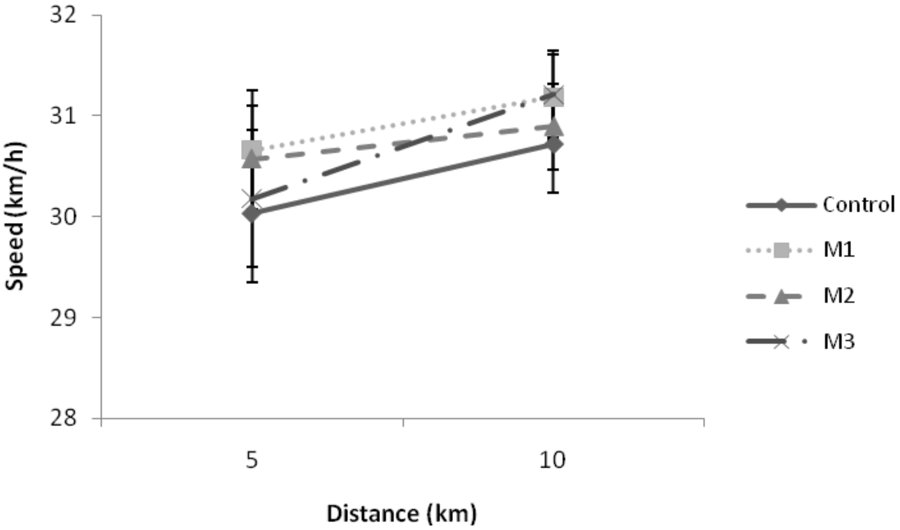

Figure 4.1. Condition x Distance interaction trendlines for mean cycling speed. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

4.3.3 Power Output

Data screening revealed no univariate outliers, and there were no violations of normality evident in tests of standard skewness and kurtosis (see Table 4.1). Given that the data met the relevant parametric assumptions, ANOVA was retained as the test of significance. Mauchly's test of sphericity revealed no violations for the assumption of sphericity for the Condition x Distance interaction ($W = .683$, $\varepsilon = .828$, $p = .162$), or the condition main effect ($W = .830$, $\varepsilon = .881$, $p = .571$).

4.3.3.1 Condition x Distance interaction. There was no significant Condition x Distance interaction, $F(3, 66) = 1.06$, $p = .373$, $\eta_p^2 = .05$, although the manipulation of these independent variables accounted for 5% of the variance, representing a small effect. The music manipulation did not induce any changes in power output generated over the course of the time trials (see Figure 4.2).

4.3.3.2 Condition main effect. There was no significant main effect for condition, *F*(3, 66) = .91, *p* = .439, η_p^2 = .04, and this independent variable accounted for 4% of the variance. Power output was on average, similar across conditions, although participants generated more power under the influence of music (see Table 4.2).

4.3.3.3 Distance main effect. There was no significant main effect for distance, *F*(1, 22) = 2.80, *p* = .109 η_p^2 = .11, although the independent variable manipulation accounting for 11% of the variance, representing a moderate-to-large effect. Minimal changes in power were observed from the first to the second half of the time trial (see Figure 4.2).

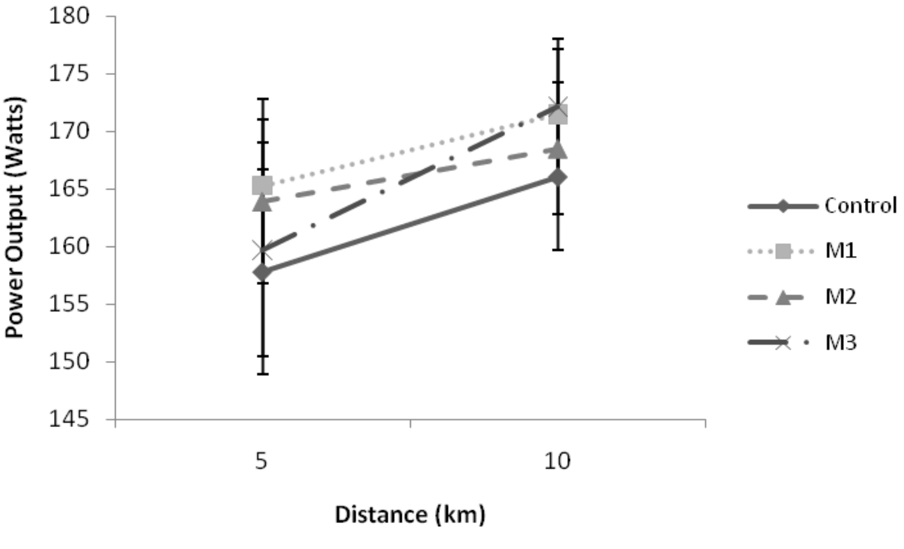

Figure 4.2. Condition x Distance interaction trendlines for mean power output. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

4.3.4 Cadence

Data screening revealed no univariate outliers, and there were no violations of normality evident in tests of standard skewness and kurtosis (see Table 4.1). Given that the data met the relevant parametric assumptions, ANOVA was retained as the test of significance. Mauchly’s test of sphericity revealed no violations for the assumption of sphericity for the Condition x Distance interaction ($W = .744$, $\varepsilon = .862$, $p = .296$), or the condition main effect ($W = .883$, $\varepsilon = .931$, $p = .766$).

4.3.4.1 Condition x Distance interaction. There was no significant Condtion x Distance interaction, $F(3, 66) = 2.574$, $p = .766$, $\eta_p^2 = .02$, and the manipulation of these independent variables accounted for 2% of the variance. The music manipulation did not induce any changes in participants’ cadence over the course of the time trials (see Figure 4.3).

4.3.4.2 Condition main effect. There was no significant main effect for condition, $F(3, 66) = 2.61$, $p = .059$, $\eta_p^2 = .11$, although this independent variable manipulation accounted for 11% of the variance, representing a moderate-to-large effect. Participants cycled at a mean cadence of 85-89 rpm across all trials, with relatively little variation (see Table 4.2).

4.3.4.3 Distance main effect. There was a significant main effect for distance, $F(1, 22) = 6.11$, $p = .022$, $\eta_p^2 = .22$, with the independent variable manipulation accounting for 22% of the variance, representing a large effect. Follow-up pairwise comparisons with Bonferroni adjustment indicated that mean cycling cadence was significantly higher ($p = .02$, $M = 1.91$, 95% CI = [.31, 3.52]) in the second half when compared to the first half of the time trial (see Figure 4.3).

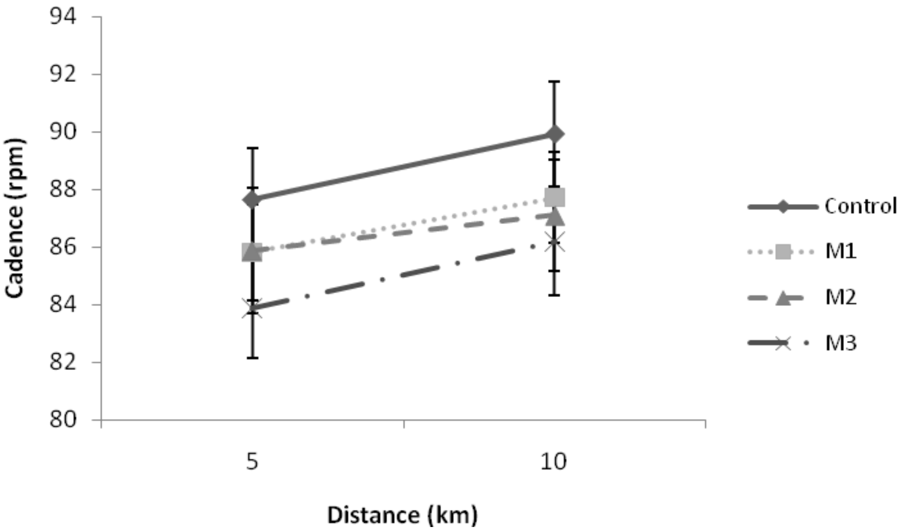

Figure 4.3. Condition x Distance interaction trendlines for mean cycling cadence. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

4.3.5 Heart Rate

Data screening revealed no univariate outliers, although tests of standard skewness and kurtosis showed violations of normality; condition M3 showed minor negative skewness and minor positive kurtosis in the first half, and severe negative skewness and severe positive kurtosis in the second half (see Table 4.1). Accordingly, data transformation was carried out in an attempt to normalise the distribution. A square root transformation (Tabachnick & Fidell, 2007, p. 87) normalised the dataset and these transformed data were used in subsequent analysis. Given that the data now met the relevant parametric assumptions, ANOVA was retained as the test of significance. Mauchly’s test of sphericity revealed no violations for either Condition x Distance interaction data ($W = .745$, $\varepsilon = .834$, $p = .298$) or condition data ($W = .749$, $\varepsilon = .856$, $p = .307$).

4.3.5.1 Condition x Distance interaction. There was a significant Condition x Distance interaction, $F(3, 66) = 2.85$, $p = .044$, $\eta_p^2 = .12$, and the manipulation of these independent variables accounted for 12% of the variance, representing a moderate-to-large effect. Separate ANOVAs were conducted to determine the source of the interaction. No significant differences were observed across conditions in either the first half ($p = .61$) or the second half ($p = .35$) of the trial. Nonetheless, there seemed to be an increase in heart rate over time for all conditions, although the rate of increase differed; under M3, the gradient was steeper in the second half of the time trial, while for M2, the gradient became shallower in the latter stages (see Figure 4.4).

4.3.5.2 Condition main effect. There were no significant main effects for condition, $F(3, 66) = .52$, $p = .672$, $\eta_p^2 = .02$, and this independent variable manipulation accounted for 2% of the variance. Participants' heart rate did not alter significantly under the different music conditions when compared to control (see Table 4.2).

4.3.5.3 Distance main effect. There was a significant effect for distance, $F(1, 22) = 68.47$, $p < .001$, $\eta_p^2 = .76$, with the independent variable manipulation accounting for 76% of the variance, representing a very large effect. Heart rate was significantly higher ($p < .001$, $M = 2.15$ bpm, 95% CI = [1.71, 2.59]) in the second half of the time trial when compared to the first half (see Figure 4.4).

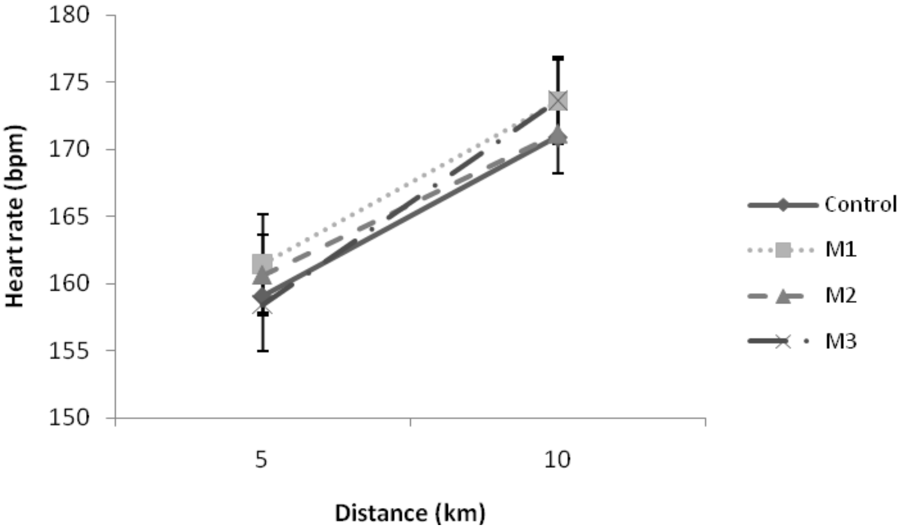

Figure 4.4. Condition x Distance trendlines for mean heart rate. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

4.3.6 Ratings of Perceived Exertion

Data screening revealed no univariate outliers, and there were no violations of normality in tests of standard skewness and kurtosis (see Table 4.1). Given that the data met the relevant parametric assumptions, ANOVA was retained as the test of significance. Mauchly's test of sphericity revealed no violations for either Condition x Distance interaction data ($W = .652$, $\varepsilon = .811$, $p = .116$) or condition data ($W = .598$, $\varepsilon = .729$, $p = .059$).

4.3.6.1 Condition x Distance interaction. There was no significant Condition x Distance interaction, $F(3, 66) = 1.07$, $p = .366$, $\eta_p^2 = .05$, and the manipulation of these independent variables accounted for 5% of the variance. The music manipulation did not induce any changes in participants' perception of effort over the course of the time trials (see Figure 4.5).

4.3.6.2 Condition main effect. There was a significant main effect for condition, $F(3, 66) = 4.80$, $p = .004$, $\eta_p^2 = .18$, and this independent variable manipulation accounted for 18% of the variance, representing a large effect.

Follow-up pairwise comparisons with Bonferroni adjustment indicated that mean RPE was significantly lower for M3 compared to M2 (p =.02, M = -.54, 95% CI = [-1.02, -.07]) and control (p =.004, M = -.50, 95% CI = [-.86, -.13]), while M1 was not significantly different (p >.05) to the other trials (see Table 4.2).

4.3.6.3 Distance main effect. There was a significant main effect for distance, $F(1, 22) = 102.13$, $p < .001$, $\eta_p^2 = .82$, with the independent variable accounting for 82% of the variance. Perceived exertion was significantly higher (p < .001, M = 2.15, 95% CI = [1.71, 2.59]) in the second half of the time trials when compared to the first half (see Figure 4.5).

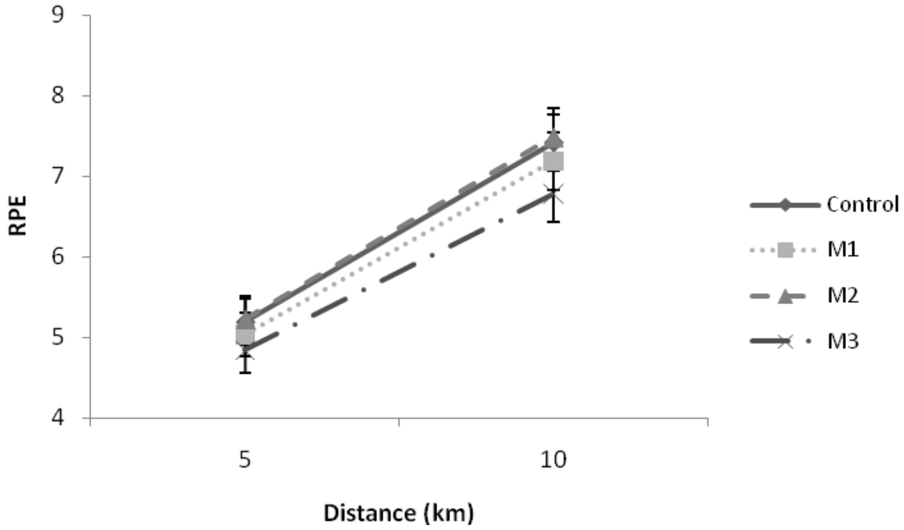

Figure 4.5. Condition x Distance interaction trendlines for mean RPE. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

4.3.7 In-task Affective Valence

Data screening revealed no univariate or multivariate outliers, while tests of standard skewness and kurtosis indicated that there were no violations of normality (see Table 4.1). Given that all parametric assumptions were met, ANOVA was retained as the test of significance. Mauchly’s test of sphericity revealed no violations for either Condition x Distance interaction data ($W = .847$, $\varepsilon = .894$, $p = .633$) or condition data ($W = .737$, $\varepsilon = .844$, $p = .276$).

4.3.7.1 Condition x Distance interaction. There was a significant Condition x Distance interaction, $F(3, 66) = 8.78$, $p < .001$, $\eta_p^2 = .29$, and the manipulation of these independent variables accounted for 29% of the variance, representing a large effect. Separate ANOVAs were conducted to determine the source of the interaction. Significant differences were found for M3 when compared to M2 ($p = .004$, $M = 1.15$, 95% CI = [.32, 1.98]) and control ($p = .01$, $M = .89$, 95% CI = [.19, 1.60]) in the second half of the time trial. Although there was a decline in mean affective valence over time for all conditions, the rate of decline differed across conditions (see Figure 4.6); M3 appeared to attenuate the decline in- affective valence far better than M2 and control.

4.3.7.2 Condition main effect. There was a significant main effect for condition, $F(3, 66) = 3.53$, $p = .020$, $\eta_p^2 = .14$, and this independent variable manipulation accounted for 14% of the variance, representing a large effect. Nonetheless, follow-up pairwise comparisons with Bonferroni adjustment did not indicate any significant differences, although participants in M3 appeared to report higher levels of affective valence compared to cycling without music ($p = .08$; see Table 4.2).

4.3.7.3 Distance main effect. There was a significant main effect for distance, $F(1, 22) = 11.34$, $p = .003$ $\eta_p^2 = .34$, with the independent variable accounting for 34% of the variance, representing a very large effect. There was a significant decline ($p = .003$, $M = -.91$, 95% CI = [-1.48, -.35]) in mean affective valence from the first to the second half of the time trial (see Figure 4.6).

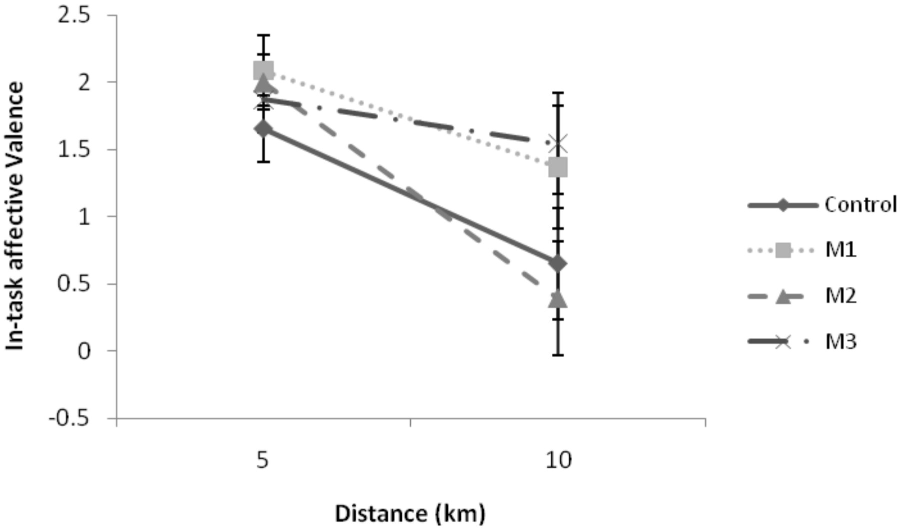

Figure 4.6. Condition x Distance interaction trendlines for mean in-task affective valence. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

4.3.8 In-task Arousal

Data screening revealed no univariate outliers, while tests of standard skewness and kurtosis indicated that there were no violations of normality (see Table 4.1). Given that relevant parametric assumptions were met, ANOVA was retained as the test of significance. Mauchly's test of sphericity revealed a violation for the condition main effect ($W = .534$, $\varepsilon = .762$, $p = .024$), but not for Condition x Distance interaction ($W = .674$, $\varepsilon = .780$, $p = .147$). Accordingly, the Greenhouse-Geisser adjustment was applied to the *F* ratio for the condition data.

4.3.8.1 Condition x Distance interaction. There was a significant Condition x Distance interaction, $F(3, 66) = 2.89$, $p = .042$, $\eta_p^2 = .12$, and the manipulation of these independent variables accounted for 12% of the variance, representing a moderate-to-large effect. Separate ANOVAs were conducted to determine the source of the interaction. No significant differences were observed across conditions in either the first half (p = .61) or the second half (p = .35) of the trial. Nonetheless, it seemed that there was a steady increase in arousal from the first to second half of the time trial for Control, M1, and M3, while in M2 arousal remained at similar levels, although this did not reach significance (see Figure 4.7).

4.3.8.2 Condition main effect. There was no significant main effect for condition, $F(2.29, 50.32) = 1.45$, $p = .244$, $\eta_p^2 = .06$, and this independent variable manipulation accounted for 6% of the variance. Mean arousal was similar across the conditions, although M1 elicited slightly higher levels of arousal compared to the other conditions (see Table 4.2).

5.3.8.3 Distance main effect. There was no significant main effect for distance, $F(1, 22) = 3.77$, $p = .065$, $\eta_p^2 = .15$, with the independent variable accounting for 15% of the variance. An increase in mean arousal was evident from the first to the second half of the time trial, although this did not reach statistical significance (p = .07). Nonetheless, the moderate effect size reported would suggest that the distance had an influence on participants' subjective arousal (see Figure 4.7).

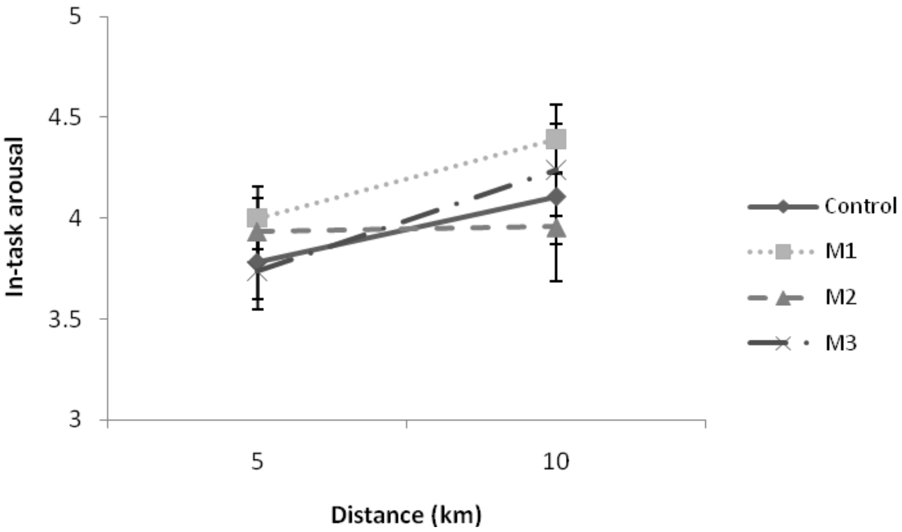

Figure 4.7. Condition x Distance interaction trendlines for mean in-task arousal. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

4.3.9 AD ACL

4.3.9.1 Energetic arousal. Data screening revealed no univariate outliers, although tests of standard skewness and kurtosis indicated that there were violations of normality; minor negative skewness and severe kurtosis were observed for M1 post-task (see Table 4.1). Given that the transformation of self-report data is not recommended (Nevill & Lane, 2007), and the *F* test was considered robust enough to withstand violations of normality (Vincent, 2005, p. 163).Moreover, there is no non-parametric alternative that is suitable for the present design. Therefore ANOVA was retained as the test of significance. Mauchly’s test of sphericity revealed violations for both Condition x Distance interaction ($W = .361$, $\varepsilon = .591$, $p = .001$), and condition data ($W = .542$, $\varepsilon = .698$, $p = .027$). Accordingly, the Greenhouse-Geisser adjustment was applied to the respective F ratios.

4.3.9.1.1 Condition x Distance interaction. There was no significant Condition x Distance interaction, *F*(1.77, 38.98) = 2.20, *p* = .130, η_p^2 = .09, and the manipulation of these independent variables accounted for 9% of the variance, representing a moderate effect. Music and the way it was manipulated did not significantly alter the increase in EA across time (see Figure 4.8).

4.3.9.1.2 Condition main effect. There was no significant main effect for condition, *F*(2.09, 46.05) = 1.57, *p* = .218, η_p^2 = .07, and this independent variable accounted for 7% of the variance, representing a small to moderate effect. Participants' EA levels were not influenced by the music manipulation (see Table 4.2)

4.3.9.1.3 Distance main effect. There was a significant main effect for distance, *F*(1, 22) = 9.57, *p* = .005, η_p^2 = .30, with the independent variable accounting for 30% of the variance, representing a large effect. There was an increase in energetic arousal (*p* = .005, *M* = 3.27, 95% CI = [1.08, 5.47]) from pre-task to post-task (see Figure 4.8).

4.3.9.2 Tense Arousal. Data screening revealed no univariate outliers, while tests of standard skewness and kurtosis indicated that there were no violations of normality (see Table 4.1). Given that the relevant parametric assumptions were met, ANOVA was retained as the test of significance. Mauchly's test of sphericity revealed no violations for either Condition x Distance interaction data (*W* = .873, ε = .920, *p* = .729) or condition data (*W* = .677, ε = .828, *p* = .152).

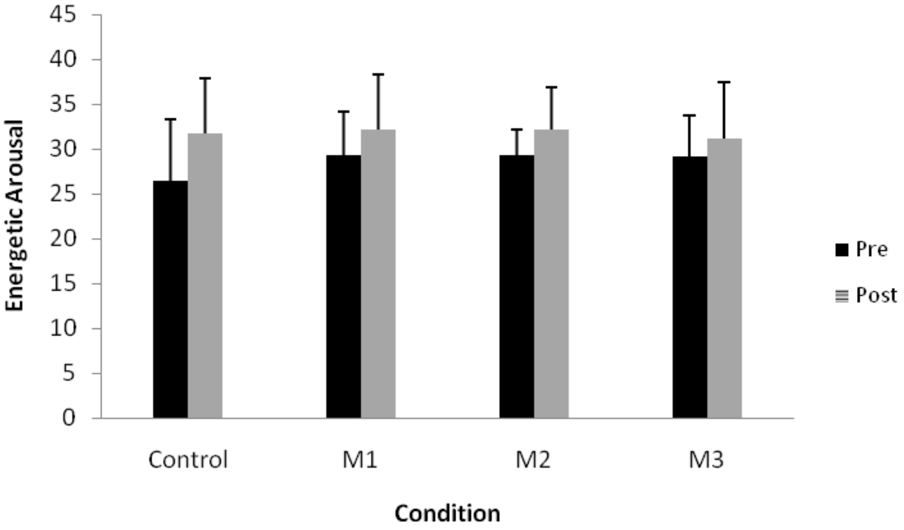

Figure 4.8. Mean EA across trials from pre to post-task. Error bars represent standard deviations. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

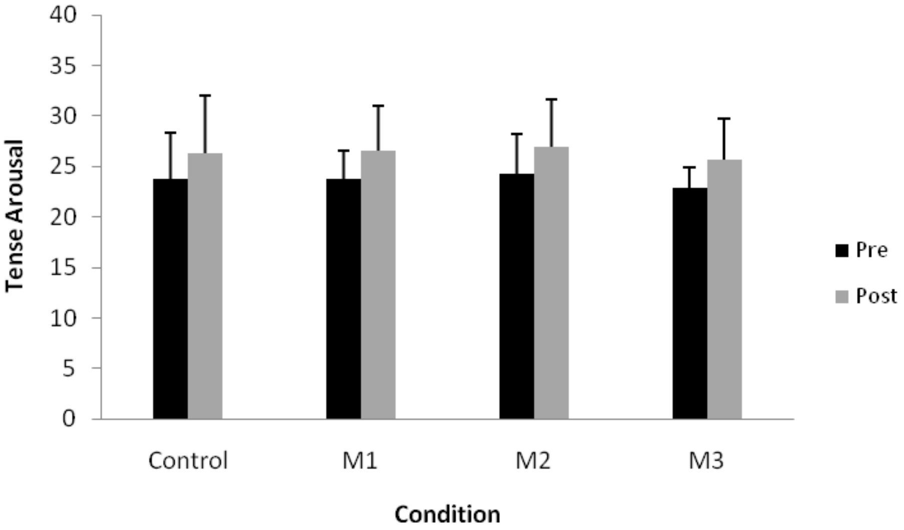

Figure 4.9. Mean TA across trials from pre to post-task. Error bars represent standard deviations. M1 = music 10 km; M2 = music 0-5 km; M3 = music 5-10 km.

4.3.9.2.1 Condition x Distance interaction. There was no significant Condition x Distance interaction, $F(3, 66) = .07$, $p = .974$, $\eta_p^2 = .003$ and the manipulation of these independent variables accounted for .3% of the variance. The experimental conditions did not appear to affect TA any differently to control from pre- to post-task (see Figure 4.9).

4.3.9.2.2 Condition main effect. There was no significant main effect for condition, $F(3, 66) = 1.32$, $p = .277$, $\eta_p^2 = .06$, and this independent variable accounted for 6% of the variance, representing a small effect. The experimental conditions did not appear to affect TA any differently to control (see Table 4.2)

4.3.9.2.3 Distance main effect. There was a significant main effect for distance, $F(1, 22) = 24.33$, $p < .001$, $\eta_p^2 = .53$, with the independent variable accounting for 53% of the variance, representing a large effect. There was an increase in TA at post-task ($p < .001$, $M = 2.71$, 95% CI = [1.57, 3.84]) compared to pre-task. (see Figure 4.9).

4.3.10 Music Preference

Data screening revealed no univariate outliers, while tests of standard skewness and kurtosis indicated that there were no violations of normality. Given that the relevant parametric assumptions were met, ANOVA was retained as the test of significance. Mauchly’s test of sphericity revealed no violation for the assumption of sphericity ($W = .947$, $\varepsilon = .950$, $p = .566$). The condition effect was not significant, $F(2, 44) = .99$, $p = .380$, $\eta_p^2 = .04$, and this independent variable accounted for 4% of the variance, representing a small effect. Preference ratings were similar across music conditions (see Table 4.2), indicating that the shortened versions of tracks in the truncated playlist did not affect participants’ musical preference.

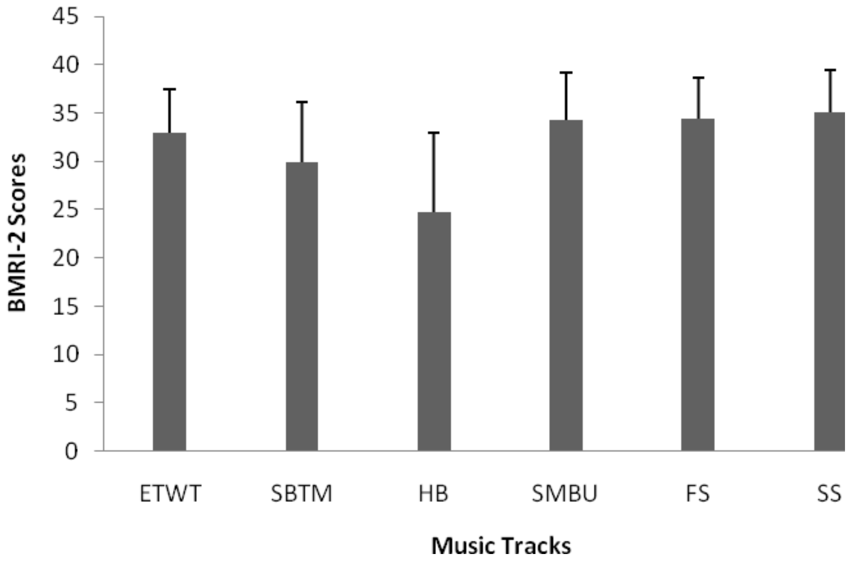

Figure 4.10. Mean motivational qualities of each track as rated by eight participants. Error bars represent standard deviations. ETWT = *Everytime We Touch* (Cascada); SBTM = *Somebody Told Me* (The Killers); HB = *Heartbroken* (T2 feat. Jodie Aysha); SMBU = *Smack My Bitch Up* (The Prodigy); FS = *Firestarter* (The Prodigy); SS = *Sandstorm* (Darude).

4.3.11 BMRI-2 Scores

Participants' ratings for the seven tracks are displayed in Figure 4.10. Mean scores for all tracks were between the range of 24-35, which indicates that they were moderate in terms of their motivational qualities (Karageorghis, 2008).

4.3.12 Qualitative Findings

Analysis of the interview transcripts revealed a total of 183 raw data themes. These were then clustered according to similarities, giving rise to 35 first-order themes. Higher-order themes were further identified through continual comparing and contrasting (Scanlan et al., 1989), and at the end of the content analysis, seven general dimensions emerged. Full results of the analysis are presented in Table 4.3. Dimensions are discussed individually in the following section, with reference to relevant order themes and quotes from the raw data.

4.3.12.1 Effects of music. Participants perceived a range of psychological, psychophysical, and ergogenic benefits associated with music listening during the cycling time trials. These include outcomes such as increased velocity, greater pleasure and motivation, as well as reductions in perceptions of effort and pain. There was also evidence to suggest that music can induce certain dimensions of flow, specifically the ability to distort time: "If you enjoy the song more or there is [sic] more lyrics to it, then you kind of zone out of cycling, so the time goes quicker, cos you're not thinking about it as much" (Participant 7). Another quote illustrates the ability of music to distract participants from the task: "The music sort of engaged my mind you know, I was sort of in my own mind rather than caring about how much I've done, how much distance I've done" (Participant 6).

4.3.12.2 Influences on music preference. Several factors emerged that participants reported to affect their music listening experience. These factors were separated into two broad sections: Intrinsic and extrinsic properties of music. Lyrical content, musical structure and rhythmical qualities make up the intrinsic properties of music. All participants mentioned a preference for fast tempo music: "…when I'm doing exercise, I prefer something with, like, a bit of a higher beat…" (Participant 3), "Something with a quick rhythm playing all the way through" (Participant 8), "You sort of link yourself with the music. With the tempo going fast, it might speed you up a bit" (Participant 6). There was also an emphasis on the contents within a track, such as lyrics and instrumentation: "Instruments more so than lyrics. I don’t listen to lyrics that much” (Participant 8), “…or there is [sic] more lyrics to it…the time goes quicker, cos [sic] you’re not thinking about it as much” (Participant 7). The repetitive nature of certain tracks was a turn-off for the majority of participants: “I think it’s harder to cycle to it because it’s quite repetitive” (Participant 7), “that song, Smack My Bitch Up, that kind of got boring, repetitive, after a while” (Participant 1), “There was one song that drags on for ages as well, that’s not good” (Participant 8).

Extrinsic properties consisted of two items, genre and repeated music exposure. Participants had contrasting musical tastes; one individual preferred to listen to music that was current: “…the music I listen to is usually in the Top 20…” (Participant 1), while two others expressed a preference for rock music: “My taste is more like rock and indie music, and like alternative. And then I don’t mind a bit of electronic” (Participant 3), “I think I like a bit of soft rock maybe” (Participant 6).

The other extrinsic factor on which participants commented was repeated exposure to the same music tracks. On the one hand, there were participants who felt that the familiarity of a musical composition was a positive element that engendered improvements in other aspects: “…it’ll probably be music that I listen to all the time…because I just think I enjoy listening to that music, and it would help me go quicker, to help me probably concentrate more and take my mind off any external factors that were hindering my performance” (Participant 4). Another quote illustrates how one participant viewed the familiarity of songs as a factor to consider in his overall cycling strategy: “Obviously if it’s songs that I know, I know roughly how long they are, and where the main points of the song [are], so there is something to set a challenge…I know the end of this song is far away, can I get to this distance before the end of the song" (Participant 3). On the other hand, there was an individual that regarded repeated exposure to the same songs to have a desensitisation effect: "They are all songs I've heard, I quite like them…but I think the more you hear them, it kind of reduces the effect it has every time you hear it. You know what's coming and you know how long for [sic], and you kind of get used to it, and it almost becomes repetitive" (Participant 1).

4.3.12.3 Music delivery. This dimension dealt with the presentation and delivery of music. For example, this quote expressed the view of one participant who felt that tracks with a long duration had a negative impact on him: "Maybe if the songs are not too long, like a minute-and-a-half or two minutes of a song, so you're not getting bored of it [then, that would be preferable]" (Participant 8). Another interesting point that emerged was the mixing of tracks, specifically the transition between songs: "Crossover between songs is important, so sort of when one finishes and the other one dips in, it's important that there isn't a sort of gap or a stop, because that can get you out of rhythm" (Participant 2). Other factors that were raised were the use of earphones instead of speakers (Participant 2), and a preference for higher sound intensity (Participant 2).

4.3.12.4 Music manipulation. In general, participants enjoyed musical accompaniment when cycling, and more importantly, the task was perceived to be easier when listening to music provided throughout or in the second half of the time trial compared to exposure in the first segment: "I thought it was easier when I had music all the way through, and then, when I had music for the last 5 km, It was definitely hardest when I had no music and music for the first 5 km" (Participant 4), "I enjoyed music all the way through, I'll say the last 5 km (M3) I enjoyed it as well" (Participant 6). The presentation of music only in the second half of the time trial was a manipulation that was well received by participants: "In particular the one with the music that came in after 5 km, I felt that one, it just felt like it went very nicely together, cos [sic] I kind of reach the end of all my effort that I could have put in on my own, and as it came on, it almost felt like I've done a 5 km and I've had like a little break, and did another 5 km, that kind of thing" (Participant 1), "With how it was set up, personally I prefer music at the end" (Participant 5).

4.3.12.5 Preference for specific tracks. This theme was included in order to illustrate the subjectivity of participants' thoughts on certain pieces of music. Most of the participants expressed a disliking for the track, *Heartbroken*: "The third one (*Heartbroken*), I think its rubbish" (Participant 8), "I didn't like the 3rd track" (Participant 7), "I think it's the 3rd track...it's not quite in my taste of music" (Participant 1). There were also differing opinions on *Firestarter*; most thought it was a good choice while one individual (Participant 1) did not share this sentiment.

4.3.12.6 Pacing strategy. This category dealt with the strategies adopted by participants to complete the task. Three distinct, but not mutually exclusive approaches were revealed: A steady pace, a two-part distance strategy, and a strong end to the time trial. Most participants favoured a constant pace for a significant portion of the time trial, with an exponential rise in speed towards the end: "I wanted to just start off slowly and gradually build up the pace and then for the last 3 km just try and go as fast as I could" (Participant 5), "I kind of wanted to set a steady pace for up until about 8 km, and then drop off a little bit, and then from 9 km onwards go really quick [sic]" (Participant 7). Although a strong finish forms part of their pacing strategies, the timing of it seems to vary across individuals. Participants also seem to prefer picking up the pace after the 5 km mark.

4.3.12.7 Perceptions of the task. Participants all agreed that the demands of the task were high, but held differing views as to which parts were harder or easier compared to others. One common theme across generally contrasting opinions was that any positive or negative perception of the task centred on the 5 km mark: "The hardest bit is when you still haven't passed the halfway mark. It's getting up to the halfway mark. Once you past the halfway [mark], it doesn't feel as bad. Because you've gone further than what you've got left" (Participant 5), "It always feels easier at the start, all the way up till about 5 km, and then it starts to dip a bit" (participant 2). Thus the terms, *midpoint drop* and *midpoint gain*, were coined to reflect changes that occur at the half-way point of the 10-km cycling time trial.

Table 4.3

Results of Content Analysis of Interview Data

Raw data themes (k = 35)	First-order themes (k = 3)	Second-order themes (k = 5)	General dimensions (k = 7)
Cycling speed		Performance outcomes	Effect of music
Pacer			
Synchronisation			
Arousal		Psychological outcomes	
External focus			
Motivation			
Pleasure/enjoyment			
In the zone	Flow		
Time distortion			
Perceived effort		Psychophysical outcomes	
Perceived exertion			
Perceived pain			

(*table continues*)

Table 4.3 (continued)

Raw data themes (k = 35)	First order-themes (k = 3)	Second order-themes (k = 5)	General dimensions (k = 7)
Pop	Genre	Extrinsic properties of music	Influences on music preference
Rock/Indie			
Music densensitisation	Repeated music exposure		
Positive familiarity			
Lyrical content		Intrinsic properties of music	
Musical structure			
Rhythmical qualities			
Listening device			Music delivery
Sound intensity			
Track duration			
Track mixing			

(*table continues*)

Table 4.3 (continued)

Raw data themes (k = 35)	First order-themes (k = 3)	Second-order themes (k = 5)	General dimensions (k = 7)
Music 1st half			Music manipulation
Music 2nd half			
Music full			
No-music control			
Constant pace			Pacing strategy
Dividing distance			
Strong finish			
Midpoint drop			Perceptions of task
Midpoint gain			
Disliked tracks			Specific track preferences
Liked tracks			

4.4 Discussion

The purpose of the present study was to investigate the psychological, psychophysical, and ergogenic effects of differentiated music exposure during a 10-km cycling time trial in which participants were given knowledge of the impending intervention prior to commencement of the trial. A relationship between psychological/psychophysical responses and performance was hypothesised; it was suggested that if the provision of music improved cycling performance, no corresponding changes would be observed for psychological and psychophysical variables, and vice versa.

Significant Condition x Distance interactions were observed for heart rate and in-task affective valence. Significant main effects were also observed for in-task affective valence and RPE, while there were significant distance effects for all variables except speed, power output, and in-task arousal. Current findings indicate that although race times were relatively similar, participants experienced significantly greater pleasure and perceived less exertion when cycling to music presented in a certain manner. Accordingly, the main research hypothesis was accepted. Each variable is discussed in depth in the subsections that follow. Quantitative results are discussed first, beginning with performance outcomes, then psychophysical observations, and lastly, psychological findings. Following on, qualitative results are critically evaluated.

4.4.1 Performance

Musical accompaniment did not enable the current participants to record significantly faster cycling times, suggesting that listening to music during a cycling time trial has no performance benefits. This was in contrast to results observed in Chapter 3 of this thesis; the previous set of participants completed the time trial faster under conditions M1 and M3 when compared to control. Two factors in the experimental design might possibly be responsible for the different observations: the arrangement of the playlist and foreknowledge of music exposure.

One of the limitations raised in the previous chapter was the inconsistent order of track presentation across participants and conditions. Specifically, at any given point of music exposure, the track that any given participant was listening to was likely to be different to that listened to by other participants. To circumvent this problem, a more consistent approach to music presentation was implemented for the present study (exact details are provided in the methodology section). Accordingly, the order of the playlist may have decreased the efficacy of the music for the current study. Nonetheless significant positive changes were observed for pleasure, as well as RPE in the presence of music, suggesting that the track arrangement did not obscure the benefits associated with music listening.

The other, more plausible, explanation for the lack of any significant reduction in cycling times may be due to participants’ foreknowledge of the conditions. The provision of such information would have allowed participants to plan their strategy accordingly. Researchers have proposed that in closed-loop exercise tasks, knowledge of the end-point allows the individual to plan their exercise strategy in order to complete the task without homeostatic disruption (St Clair Gibson et al., 2006). It was also suggested by St Clair Gibson and colleagues that situational and motivational factors can influence the approach to the task at hand. In the current study, although participants might have gained some benefit from music listening (i.e., perceived less exertion and displeasure) that could have enabled them to work at a higher workload, they may have decided not to sacrifice these gains to achieve better performance. Nonetheless, although no significant reductions in race times were observed in the present study when participants were cycling to music, there was a trend in this direction, with music conditions eliciting faster cycling times compared to the no music control (see Table 4.1).

The present findings also seem to indicate that the manipulation of music exposure influenced participants' cycling strategy, as evident from the Condition x Distance interactions for speed, power output, and cadence. Although the interactions were not significant ($p > .05$), participants appear to generate greater velocity/force only in the presence of music, and no carry-over effects of music, at least not for performance indices, were observed. The current profiles for speed and power output are identical in trend and direction to those reported in Chapter 3 of this thesis, indicating that prior knowledge of the music intervention did not significantly alter participants' cycling strategies in comparison to when they had no knowledge about the impending conditions. Alterations in power output were also observed by Joseph et al. (2008); participants in their study were required to complete three 5 km cycling time trials. Unbeknown to the participants, they had to perform two of the trials under different hypoxic conditions at varying distances. Reductions in power output were immediately observed with the introduction of hypoxia, and stayed at this depressed level for the duration of the exposure. Taken collectively, these findings indicate that unexpected changes to the external environment are more likely to lead to stronger performance effects. Moreover, they would lend support to the notion of teleoanticipation (Ulmer, 1996), and how such a process can rapidly adjust work rate or effort to changing circumstances (St Clair Gibson et al., 2006).

A comparison of the current speed profiles of M2 and M3 to those previously reported by Lim et al. (2009) revealed interesting differences. In particular, Lim et al. observed that the significant interactions for speed were due to participants being exposed to music in the second half of the time trial; under this condition, participants seemed to generate greater speeds in the early stages of the time trial. No such increments were noted when participants cycled without music or with music presented only in the first half. In fact, the speed profiles for these two conditions were identical. Lim et al. suggested that participants may have considered the condition where music was presented in the second half as more beneficial to overall performance, and thus incorporated it into their pacing strategy.

Such speed profiles were not replicated in the present research for similar experimental conditions, suggesting that some other factors may be responsible for this contrast. One such factor could be related to the population sample. Lim et al.'s (2009) sample, although heterogeneous in terms of ability and experience, contained individuals who were more familiar with the modality of the task and than others. For example, a couple of their participants were triathletes, and two were competitive cyclists. Although the level of fitness of the current sample was not considered inferior, some were competing at collegiate level; none of the participants were actual cyclists. Therefore, there is a likelihood that experience may moderate the type of pacing strategy one chooses. Further research is required to assess if this is indeed the case.

4.4.2 Heart Rate and RPE

The lack of any significant changes in heart rate would seem to indicate that participants were working at the same physiological level across the trials. Kinematic efficiency resulting from possible music synchronisation, either conscious or subconscious, can be ruled out considering the lack of cardiovascular changes in light of the performance data. Moreover, the changes in heart rate across conditions appear to be influenced by the introduction and removal of music, as evident from the significant interaction reported. The pattern of change was similar to that observed for the current profiles of speed and power output. This is no surprise: The generation of higher workloads should lead to increased cardiovascular strain, unless there were metabolic or movement efficiencies. Accordingly, alterations in heart rate were not a direct consequence of music listening but were rather due to the physiological demands associated with workload.

Current findings pertaining to participants' perceived exertion suggest that the efficacy of music as a distractive stimulus is very much dependent on the manner in which it is presented to participants, at least for closed-loop exercise. Participants listening to music for half the distance of the time trial (M3) reported significantly lower RPE scores to control, whereas no significant differences for RPE were observed between control and M1. These results suggest that prolonged exposure to a supposedly pleasant and dissociative stimulus such as music may reduce its effectiveness; it would appear that less can be more in such instances. Moreover, the benefit is governed by the point of exposure: Reductions in perceived effort were only observed in M3. Participants cycling to music during the first 5 km reported similar perceptions of effort to when they were cycling without music. Further, RPE was significantly lower for M3 throughout the entire distance and not just during the last 5 km of music exposure, possibly indicating that RPE was dictated prior to the start of the trial as a result of knowing about the impending music intervention. This is a particularly interesting finding, considering the relationship between RPE and pacing strategies. Researchers have proposed that pacing strategies are determined by a pre-programmed RPE template, and that the work output is adjusted accordingly to ensure that this template is adhered to (St Clair Gibson et al., 2006).

In Joseph et al.'s (2008) study, RPE across all trials was similar despite significant decrements in power output during periods of hypoxia. Indeed, observations in the previous chapter do provide some support for this concept; RPE was maintained at similar levels across trials despite improvement in performance. Nonetheless, the present findings indicate that the RPE template is not fixed and depending on the right conditions, can be manipulated without any detrimental consequence to physical performance. Moreover, judging by the results of the current study and those reported in the previous chapter, it would appear that foreknowledge of the intervention had an influence on how exertion was perceived.

4.4.3 Affective Valence and Arousal

Affective valence and subjective arousal were assessed before the start of trials, during the task itself, and at the end of the trial in order to gain a comprehensive understanding of the influence of music on these variables. There was an increase in Energetic Arousal and Tense Arousal from pre to post trial, as one would expect; it is well documented in the literature that exercise has the propensity to improve mood-related constructs (Ekkekakis, Parfitt, & Petruzzello, 2011). In addition, the rise in both dimensions was similar across trials, suggesting that there were no carry-over effects associated with music listening in the trial itself.

In terms of in-task responses, the significant decline in valence over time possibly indicates that participants were working at a physically demanding level that was probably beyond their ventilatory or lactate thresholds (Ekkekakis et al., 2008). More important, results suggest that music presented for the whole trial and music presented in the latter stages significantly attenuated the decline in affective valence associated with the physical demands of the task. The impact of this attenuation can be considered to be relative strong; significantly higher overall mean ratings of pleasure were reported by participants in M1 and M3. In Chapter 3, similar affective valence changes were only reported for M3, while participants cycling in M1 exhibited the same level of decline in affective valence as in C and M2. This would suggest that prior knowledge of the music conditions had a considerable influence on how music affected participants.

A closer scrutiny of Figure 4.6 shows that the attenuation of affective valence decline only happened in the second half of the time trial for both M1 and M2. Therefore, it could be argued that any effects of music were specifically due to its presence in the latter stages of the time trial, and that music presented in the first half had a negligible influence on affective valence. It is currently unclear why this is the case. A plausible explanation maybe that the influence of music on affective valence becomes more pronounced as it drops below a certain threshold. Decreased motivation (Frederick, Morrison, & Manning, 1996), accumulating fatigue (Backhouse, Ekkekakis, Biddle, Foskett, & Williams, 2007), and increased perceived exertion (Baden et al., 2005) are some factors that could contribute to declines in affect valence, and are more likely to occur in the latter half rather than the initial stages of the time trial. Therefore, it appears that music not only has an influence on affective valence, but also on other affect-related components such as motivation, fatigue and perceived exertion.

Another explanation that could explain why M1 did not have as strong an effect as M3 is the possibility of overexposure to the music stimulus. Berlyne (1971) propounded that during music listening, individuals take into consideration various aspects of the music such as its complexity and novelty, which are considered properties that have arousal potential. He also proposed that repeated or overexposure would lead to progressive loss of novelty, resulting in the derivation of less pleasure from the music stimulus (Berlyne, 1970). Accordingly, participants cycling with music for the entire distance may have grown weary of the music such that any potential effects that could have resulted from music exposure in the latter half of the time trial were severely limited. Indeed, this suggestion is supported by the qualitative data obtained from participants, which will be covered in more detail in section 5.4.4.

Subjective arousal, or activation, also appears to have been affected by a combination of the intervention and the distance of the task, although the interaction can be considered practically insignificant. Given that music did not elicit any changes in heart rate, it is entirely reasonable to see that no corresponding changes were observed in arousal, given the close relationship that these two factors share. Further, it seems that arousal and heart rate levels are linked to performance or work output, indicating that music does not exert a strong influence on arousal, at least not during self-paced exercise.

4.4.4 Qualitative Analysis

The qualitative results obtained from the interview process by and large corroborate existing theory and research. For example, the effects of music that participants reported qualitatively, such as enhanced pleasure, increase in physical performance, and reduced perceptions of exertion, are well supported by extant theory (c.f Terry & Karageorghis, 2006; Terry & Karageorghis, 2011). However, certain effects associated with music emerged that warrant further discussion.

It has been proposed by some researchers that music listening can induce flow in athletes (Pates et al., 2003), but empirical evidence is scarce. The present findings provided some support for the relationship between music and flow; a few participants felt that listening to music while cycling seemed to make time pass faster. Such an experience could be viewed as a form of time distortion, otherwise known as *transformation of time* in flow theory (Csikszentmihalyi, 1990). Interestingly, mean race time was not significantly different across conditions, although cycling times were faster under the experimental conditions.. This possibly suggests that participants' perceptions of time passing faster may be a reflection of the shorter race times.

Csikszentmihalyi (1990) proposed that time distortion is a consequence of total concentration on the task, which may appear to be a direct contradiction to the current findings, given that flow was mentioned only in the presence of music. Nevertheless, the task of cycling can be deemed a gross motor task that most people are familiar with, and accordingly, not much attentional resource is devoted to it. In this case, participants could have directed their focus solely upon the musical stimulus.

Among the performance outcomes of music listening mentioned by participants, synchronisation was an element that was mentioned by at least half of the interviewees. Given that participants were not instructed to actively match their pedalling frequencies to the beat of the music at any point of the time trials, these quotes suggest the possibility of implicit synchronisation, or at least the perception of synchronisation was experienced by participants. A strict auditory-motor synchronisation (Kenyon & Thaut, 2003; Repp, 2005) is unlikely, considering that the playlist consists of music in the tempo 135-141 bpm. In order for music synchronisation to occur, participants would have to be maintaining an estimated cadence of between 67-70 rpm per full pedal revolution, or 135-141 bpm per half pedal revolution. But the cadence profiles (see Figure 4.3) would suggest that this was certainly not the case.

Participants may have constructed some other mathematical model of synchronisation that was unique to them. For instance, in a study investigating walking synchrony and music, Styns, Van Noorden, Moelants, and Leman (2007) observed that although most of participants implicitly synchronised their walking patterns to music, there were times where synchronisation happened at every half or every second beat. The authors also suggested that there were other aspects of music unrelated to tempo, such as meter or the number of musicians that may influence synchronisation. These findings would lend support to the notion that humans have a propensity for auditory-motor synchronisation (e.g., Kornysheva, von Cramon, Jacobsen, & Schubotz, 2010; MacDougall & Moore, 2005; Schneider, Askew, Abel, & Strüder, 2010). Equally plausible is the notion that participants in the present study merely perceived that they were synchronising their pedal movement to the beat of the music. In reality, they just sped up their pedalling frequency in an attempt to match their cadence to the musical tempo. Although it has been proposed that participants could have synchronised their movements to musical structures unrelated to tempo, it seems an unlikely possibility given that participants have no musical background and thus would find it difficult to discern other, more subtle, aspects of music.

Another interesting theme to emerge from the data was the subject of motivation. In general, participants felt that music served as a form of motivation, providing them with an extra impetus to complete the task. They appeared to favour the introduction of music at the midpoint, followed by the condition in which music was played throughout. Participants perceived that the removal of music at the midpoint to have severe motivational consequences, and would avoid using music in such a manner. This perception is corroborated by participants' expression of a preference for conditions M3 and M1 when compared to M2 and control.

Participants were also asked to comment upon factors that would influence their music preferences. Findings on the whole were in line with extant literature; aspects such as lyrics, the way a piece is structured, and rhythmical qualities have all previously been put forward as important determinants of music preference (Bishop et al., 2007; North et al., 2004; Priest & Karageorghis, 2008). The repeated exposure to the same tracks was a significant issue raised by participants. Some found that the repetition facilitated a level of familiarity that enhanced their listening experience, while others felt that such repetition precipitated a sense of boredom.

Although participants' views were equivocal, they nonetheless fit Berlyne's (1970) early predictions and the inverted-U relationship between hedonic tone and arousal potential. This was a particularly significant finding, as this relationship has mostly been supported quantitatively (North & Hargreaves, 2008). Moreover, the repetitive nature of certain tracks was a source of discontent for some participants, and may in part explain why the presentation of music for the entire duration did not elicit higher levels of pleasure when compared to music presented only in the latter stages of the time trial. It is quite possible that any gains associated with music listening were ameliorated by the prolonged exposure to music under condition M1. Under conditions M2 and M3, tracks were shortened, and thus can be considered less repetitive than the original versions.

4.4.5 Practical Implications

Findings from the present study have significant ramifications for both exercisers and exercise practitioners. Pleasure and exertion have both been linked to exercise adherence (see Ekkekakis et al., 2011), hence it is likely that changes in either factor could impact upon one’s continual participation in physical activity. This is vitally important, particularly for exercise practitioners, as exercise adherence is an ongoing issue that is far from being comprehensively resolved in Western countries. It appears that the use of music during exercise may be a viable tool in tackling non-compliance to an exercise programme. Specifically, the presentation of music in the second half of an exercise session can significantly increase the pleasure one derives from participating, and at the same time, reduce the perception of exertion, making the activity seem more enjoyable and less of an effort.

The same idea is also applicable to practitioners involved with physical rehabilitation. Logically, it would not be wrong to surmise that patients undergoing rehabilitative exercise programmes would tend to experience more discomfort or pain than regular exercisers because of their injuries or conditions. Accordingly, providing music during these sessions could potentially alleviate the feelings of discomfort or pain being experienced by patients.

Present findings are of relevance to athletes as well, who normally have to undertake a large volume of training; listening to music in the latter stages of a training session could possibly make training bouts more pleasurable and feel less strenuous. Alternatively, athletes could possibly increase their training intensity without suffering elevated levels of displeasure and/or perceiving increased exertion by having music throughout the entire training session. Although participants’ race times in the present study were not significantly faster under the influence of music, there was a trend in that direction. In addition, there have been anecdotal reports on the use of music in competitive cycling, via short-wave radio communication systems (Atkinson et al., 2004), suggesting that music can also be applied in actual competition scenarios. Atkinson et al. also proposed that music be broadcast through public address systems during attempts at individual records, an idea that has been espoused by professional athletes (e.g., Haile Gebrselassie).

The qualitative data strongly indicate that music preference is subjective, although there are certain, more general themes that are relevant to most people, regardless of personal views. It is likely that musical pieces that have repetitive structures or are repetitive in nature do not appeal to exercisers (see Section 5.3.12.2). Accordingly, instructors conducting exercise-to-music classes such as aerobics or spin may wish to consider the use of tracks that have a more varied musical structure. Moreover, given that spinning classes are cycling based, the music manipulations used in the present study could apply in such gym classes. It is also clear that providing a musical stimulus over an extended period could potentially desensitise individuals to the pleasurable benefits associated with music listening. Thus, users may wish to listen to music only during the latter stages of an event or task, in order to fully maximise the psychological and psychophysical benefits associated with music exposure.

4.4.6 Limitations

There were several limitations evident in the present study that warrant mention. Firstly, the six musical pieces chosen for the present study were not in the upper range (36-42) of the BMRI-2 in terms of their motivational qualities (22.8-29.6). Indeed, motivational quotients obtained from the eight interviewees were similar to those obtained by the initial rating panel. Accordingly, it is plausible that presented with music of significantly higher motivational qualities, participants might have experienced positive effects above and beyond those reported.

Nonetheless, the present findings indicate that moderately motivating music can elicit certain psychological and psychophysical effects.

Another limitation is the tempo of the music. The tempi range for tracks in the present study was selected based on previous studies of a similar nature. Moreover, a series of heart rate and music tempo studies (e.g., Karageorghis et al., 2006, 2008, 2011) have indicated that exercisers expressed a preference for music tempi in the range 125-140 bpm across all exercise intensities in the submaximal range. These recommendations were taken into account and implemented during the music selection process. Yet several participants expressed in the interviews that they would prefer to have faster music tempi than those used. The difference in tempo preference could be a function of task requirement; in a cycling time trial, the objective is to complete the task in the fastest time possible. In such a case, preference for faster tempi might be linked to the facilitation of auditory-motor synchronisation or greater work output (Kornysheva et al., 2010; Kenyon & Thaut, 2003; Molinari, Leggio, & Thaut, 2007; Rossignol & Melvill-Jones, 1976) both of which could aid in the attainment of the objective. Therefore, the use of faster tempo music could possibly result in better outcomes, and is an area worthy of further investigation. Nonetheless, most up-tempo pop, rock and dance music is typically in the range of 115-140 bpm, and there are relatively few recordings that are above this range (Karageorghis et al., 2011); accordingly researchers may encounter difficulty in obtaining music at the required tempi.

The cycling experience of participants may also have influenced the present results. As previously mentioned, the experimental sample consisted of individuals who were meant to be physically fit and took part in regular exercise, or competed in collegiate sports. Nonetheless, only a handful of participants had prior experience in road racing. Although most participants cycled recreationally, a 10-km time trial is an entirely different task to recreational cycling and requires a distinct approach to complete it effectively (see St Clair Gibson et al., 2006); the task demands and effort expended in the two contexts contrast markedly.

Another potential limitation concerns the ecological validity of delivering music via speakers; it can be argued that in reality, most exercisers are likely to use earphones, rather than employing speakers to listen to music Indeed, this issue was raised by a participant in the interview, suggesting that this might have affected the efficacy of music. Nevertheless, it is unclear whether delivering music via speakers or earphones/headphones has differing outcomes on the effects of music on exercise participants. To date, researchers in the domain have been addressing more fundamental questions pertaining to music per se rather than the mode of music delivery. Nonetheless it would be interesting to examine whether different delivery modes can impact upon the music listening experience of participants.

There has been no research in the literature that examines the various effects of music across different populations. It has been suggested that older exercisers derive less enjoyment from listening to music while exercising compared to younger participants (see Priest & Karageorghis, 2008), although this may be due to a the lack of consideration for age-congruent music (Karageorghis & Priest, 2011b) In addition, only two studies have examined the moderating factor of experience on the influence of music (e.g., Brownley McMurray, & Hackney, 1995; Mohammadzadeh, Tartibiyan, & Ahmadi, 2008). It has been proposed that elite athletes favour the use of more associative attentional strategies, while inexperienced athletes prefer the opposite (Morgan & Pollock, 1977). Accordingly, the distractive capability of music may be more potent to the latter group. Further assessment is required to ascertain whether this is indeed the case.

4.4.7 Future directions

Present findings indicate that the presentation of music during the latter half of a 10-km cycling time trial has superior benefits when compared to providing participants with music for the entire duration of the task. The next step then would be to determine how best to segment music exposure in order to maximise its associated benefits. For example, researchers may wish to investigate the impact of music exposure during the middle section of the race. The distance around the 5-km mark has been identified by participants in the current study to be the most arduous segment of the 10-km cycling time trial (see Section 5.3.11.7). Moreover, the most significant benefits associated with music listening were observed in M3, wherein music was provided only for the last 5 km. Therefore, the provision of a pleasant musical stimulus at this point appears to elicit the most potent effects. Alternatively, researchers could also consider the presentation of music in a sporadic manner, similar to how Lucaccini (1968) employed music in his vigilance experiments. Such sporadic music presentation could potentially minimise the effects of music desensitisation due to overexposure, and is an avenue worthy of further investigation.

Researchers may also wish to utilise music that has a higher motivational quotient, as well as a tempi range that is beyond the upper limit of the present study. Both developments would serve to maximise the possible benefits participants might derive from music listening, and may lead to more pronounced outcomes than those already observed in the current studies. Going one step further, the self-selection of music should be given consideration as it ensures the motivational impact of music would be specific and fully maximised for each participant. In fact, North et al. (2004) reported that individuals choose different genres of music to elicit different effects, and preference is highly subjective. Nonetheless, some might argue that there is a possibility of expectancy effects (Thomas, Nelson, & Silverman, 2011), although it can be countered that researchers in studies such as the present one and those of Lim et al. (2009) are more concerned with the effects of the music manipulation rather than the music per se. Another potential problem concerning self-selection of music is the assumption that participants are apt at choosing the appropriate type of music for the activity, which is not always the case. A plausible solution could be to have researchers establish a database of suitable music of sufficient motivational qualities, and then allow participants to choose from a pre-ordained list. Such a move would minimise the chances of participants erroneously picking inappropriate music for the task, while at the same time affording them a degree of autonomy in the selection of music. Deci and Ryan’s self-determination theory (Deci & Ryan, 1985; Ryan & Deci, 2000) posits that three fundamental needs should be satisfied for people to be intrinsically motivated.Thus affording participants some autonomy in the music selection process might increase their motivation levels. Researchers could conduct future research to assess if there are any differences between music chosen via the normal BMRI-2 selection process and that chosen using the aforementioned method.

It might also be interesting to investigate if the effects of music manipulation are mediated by the duration or distance of the event/task. For example, one would expect more fatigue and less motivation the longer an event carries on (Lucaccini & Kreit, 1972). In such instances, the provision of a pleasant distracting stimulus may engender greater benefits than if the task was of a short duration. Certainly, in studies examining short-duration task, exercise intensities tend to be relatively high, which means that it is likely to be less effective than at low-to-moderate intensities (cf. Rejeski, 1985; Tenenbaum, 2001).

Researchers should endeavour to investigate if the observed effects of differentiated music exposure are translatable to other endurance type tasks. Traditionally, the influence of music has been examined across a wide array of exercise modalities, such as walking (Becker, Chambliss, Marsh, & Montemayor, 1995; Crust, 2004b), running (Birnbaum et al., 2009; Elliot et al., 2004; Tenenbaum et al., 2004), and rowing (Rendi et al., 2008), although none of these studies used a segmented music approach. Thus, it is unclear if similar observations would be reported under different exercise modalities. Theoretically, there is no reason to believe that the manipulation of music would not elicit similar benefits under different exercise modalities, but this requires further empirical investigation.

4.4.8 Conclusion

The present findings clearly indicate that manipulating music exposure, coupled with participants' foreknowledge of the interventions led them to experience less displeasure compared to cycling in a no-music control condition. Although no significant differences were observed for race times, participants perceived lower exertion in completing the time trial when presented with music in the second half as opposed to having music in the first half and under a no-music control condition. Participants also reported greater pleasure when listening to music for the entire duration of the task and for only the second half when compared to the remaining conditions.

Results from the current study are in contrast to those reported in Chapter 3, as they suggest that foreknowledge of the music interventions has a significant influence on the dependent variables under investigation. Specifically, the provision of such information enabled participants to devise a suitable pacing strategy for the 10-km cycling time trial. Such a strategy would consider how best to complete the task in the shortest time possible without severe disruption to homeostatic functioning. These findings do not fit into the theoretical propositions of a pre-programmed RPE template and how performance is regulated to maintain it (see St Clair Gibson et al., 2006). It is evident that the presentation of music in the second half of the time trial can lower one’s perception of exertion and increase pleasure while facilitating the same level of performance as the no-music control. Although several limitations were identified, some of these factors are more likely to affect the magnitude rather than the direction of the current results. For example, considering that positive changes were observed in the present study even though the music possessed moderate motivational qualities and tempi, it is reasonable to assume that the selection of pieces with higher motivational quotients and tempi would augment the effects of music.

These findings have considerable implications for researchers, athletes, and those concerned with exercise adherence. Presenting findings suggest that the manipulation of music exposure has a significant bearing on participants’ perceived exertion and affective valence. The observation that music presented in the second half of the time trial was superior in terms of attenuating both the decline in pleasure and rise in perceived exertion, even more so than when music was presented for the entire duration indicates that listening to music for an extended period of time is not necessarily the best option. This is a really interesting observation that warrants further investigation, as listening to music throughout a task was expected to elicit the most positive psychological and psychophysical responses. Future researchers may wish to examine the effects of presenting music in an intermittent manner as opposed to two different segments. They may also consider omitting condition a condition with music in the first half of the task, given that its effects are negligible..

Participants in the present study listening to music in the latter half of the time trial were able to sustain similar workloads to the control condition, while perceiving less exertion and pleasure. These benefits can improve an athlete’s or an exerciser’s training regime by making it a more enjoyable and less strenuous experience. Moreover, such benefits can have a positive impact on exercise adherence. It has been suggested that pleasure is a factor that strongly determines exercise causation and adherence (Ekkekakis et al., 2011). Thus, music listening could prove to be an extremely useful and effective aid in getting people to partake in physical activity and embrace an active lifestyle. Given the relative ease of use and application of music, along with the low costs associated with constructing music programmes, more should be done to advocate the joys of exercising to music. Further, users should also be properly educated in the different methods of music utilisation, in order that the benefits associated with music listening can be maximised.

Chapter 5: Effects of Synchronous versus Asynchronous Music on a Short Submaximal Cycling Task

5.1 Introduction

A large proportion of music-related research in the domain of sport and exercise has focussed on the various effects of asynchronous music. Asynchronous music can be defined as music played in the background to which the participant does not consciously synchronise their movements (Karageorghis, 2008). Researchers have shown that the application of asynchronous music can afford a wide range of benefits that include improved mood (Elliot et al., 2004, 2005), reduced perceptions of effort at low-to-moderate exercise intensities (Boutcher & Trenske, 1990; Nethery, 2002), increased task endurance (Copeland & Franks, 1991; Crust & Clough, 2006; Szabo et al., 1999), and enhanced sporting performance (Atkinson et al., 2004).

By way of contrast, relatively few studies have addressed the use of synchronous music, even though its application among sport and exercise participants is widespread. Synchronous music has been defined as music that is used in a deliberate manner to coordinate an individual’s movement patterns to the musical beat or tempo (Karageorghis, 2008). Music synchrony is based on the notion of auditory-motor synchronisation, which is predicated on sensorimotor synchronisation. Simply put, sensorimotor synchronisation is a type of behaviour whereby the execution of an action is matched precisely to an external event that is usually periodic in nature (Repp, 2005).

Synchronising movement to music is prevalent in a variety of sport and exercise activities: Olympic events such as rhythmic gymnastics and synchronised swimming, and gym-based exercise programmes such as spinning and aerobics classes, are just a few examples. Despite its prevalence in everyday life, there has not been a systematic programme of research into the synchronous application of music, at least in a sport and exercise context. However, the few studies that have been conducted do consistently demonstrate that the application of synchronous music engenders significant psychological, psychophysical, and ergogenic effects among recreationally active individuals performing repetitive motoric tasks (e.g., Anshel & Marisi, 1978; Hayakawa et al., 2000; Karageorghis et al. 2009; Simpson & Karageorghis, 2006).

5.1.1 Current Research

Sport and exercise researchers have generally assumed that the psychological and psychophysical effects of synchronous music are derived through the same processes as those proposed for asynchronous music (Karageorghis et al., 2009, 2010). However, due to a severe paucity of research that directly investigates these two music conditions within the same experiment, it is currently unknown if the psychophysical and psychological effects engendered by synchronous music are any different to those reported for asynchronous music use. It is also unclear if the ergogenic effects are superior for one application versus the other.

There was, however, one study that did investigate the effects of both synchronous and asynchronous music; Anshel and Marisi (1978) examined the effects of synchronous and asynchronous music on stationary cycling endurance (first two sentences merged). They reported that participants cycling to synchronous music were able cycle for significantly longer durations than in asynchronous music or a no-music control conditions. Moreover, no differences were observed between asynchronous music and the control conditions. They also reported significant gender differences; males endured for significantly longer when compared to their female counterparts, even though they were cycling at the same relative intensity. Anshel and Marisi cited Broadbent’s (1958) theory of selective perception and Hernandez-Peon’s (1961) theory’s of narrowed attention, both of which pre-dated Rejeski’s parallel processing model (Rejeski, 1985), as a plausible explanation for the observed increase in cycling endurance. However, based on these theories, participants in the asynchronous music condition should also fare better at the task when compared to the no-music control. This is because asynchronous music can be considered a competing external stimulus, and thus should be equally effective at diverting attention away from internal cues. Yet results appear to indicate that this was not the case; participants were not affected by listening to asynchronous music while cycling. Further, given that the idea of synchronous music is to match one’s movement patterns to the rhythmical qualities of music, it is difficult to envisage how an attentional processing theory might explain the superior endurance of participants listening to synchronous music when compared to asynchronous music. It could be argued that the synchronous application of music prolongs the efficiency of the attention diversion, leading to increased endurance at the task. Yet there is no evidence or theory to suggest that this is the case.

Anshel and Marisi (1978) highlighted a possible limitation of their study that has subsequently influenced other researchers. They attributed the gender differences observed to the possibility of *social influence*. The presence of a male experimenter may have caused some female participants to reduce the amount of effort they exerted. Specifically, they might have been unwilling to cycle longer as the demands of the task could have caused excessive perspiration and forced respiration, images that they might not want to portray to the opposite gender. Another limitation, one not mentioned by Anshel and Marisi, was the arbitrary manner in which the music was selected; factors such as an individuals' musical preference, age, their sociocultural background, prior experiences and associations, and exposure to media all play a part in determining one's response to a particular musical piece (Lucaccini & Kreit, 1972; Karageorghis & Terry, 1997; Karageorghis et al., 2006).

It is possible that both social influence and haphazard music selection confounded some of their findings. Nonetheless, these limitations are more likely to affect the magnitude of the observed findings rather than the results itself; even though females underperformed relative to their male counterparts, they still performed better with synchronous music when compared to the other conditions. Further, the choice of music was similar in both experimental conditions. Thus, the question of why participants did not fare better in the asynchronous music condition compared to the no-music control remains unaddressed. Nevertheless, it is important to note that this research was one of the few studies to compare synchronous versus asynchronous use of music.

An alternative explanation might be found in the experimental design of the study: Participants in both the asynchronous music and no-music control condition were provided with a metronomic visual stimulus to maintain the required cycle cadence. Accordingly, both of these conditions are arguably also synchronous conditions that utilise a visual stimulus as opposed to a musical tempo to maintain pedalling frequency. Thus participants in the asynchronous music condition had two different sources of external information to process, both auditory (background music) and visual (flickering light), compared to the no-music control, where they only attended to a visual stimulus. The additional information load may have negated any potential influence of asynchronous music. Ostensibly, the provision of a visual metronome in the asynchronous and no-music control conditions compromised the internal validity of Anshel and Marisi’s study as the synchronous application of music could not be properly isolated. Future researchers should be cognisant of this design issue when conducting studies that aim to isolate the effects of synchronous music.

Similar performance benefits have also been reported more recently: Karageorghis and colleagues observed that recreational athletes recorded quicker times in a 400-m sprint (Simpson & Karageorghis, 2006), walked further during a treadmill task (Karageorghis et al., 2009), and completed more repetitions of circuit-type exercises (Karageorghis et al., 2010) under the influence of motivational synchronous music compared to oudeterous (neutral) synchronous music, and a no-music control. In some of these instances, psychological and psychophysical effects were noted in addition to ergogenic effects (Karageorghis et al., 2009, 2010). In a recent study, improved running performance and psychological affect were observed for elite triathletes synchronising their running frequency to music in comparison to no music (Terry et al., 2012), possibly indicating that the benefits associated with synchronising movement to music are not only restricted to recreational participants.

The aforementioned studies, however, did not compare asynchronous music against synchronous music; such a comparison would have provided empirical evidence of how both applications affect an individual, not only ergogenically, but psychologically and psychophysically. It could be argued that such an inclusion would have necessitated another two conditions – motivational asynchronous music and oudeterous asynchronous music, rendering these studies impracticable to execute. However, it is this author’s opinion that the need to examine the differential effects of asynchronous versus synchronous music far outweighs the need to determine the consequences of motivational versus oudeterous synchronous music. It is necessary, first and foremost, to examine if there are any differential effects in both music application. Intuitively, one would expect to observed discernible differences between the applications, but this has yet to be empirically proven. Therefore, there is a possibility that individuals are affected similarly by both applications of music. If this is indeed the case, there would be no need for the separation of music research into synchronous and asynchronous applications. Although this is unlikely to be the case, it is the role of scientific research to rule out this possibility. Therefore, it is imperative that future researchers seek to establish whether the effects of asynchronous and synchronous music differ in any way before investigating the influence of the motivational qualities of music.

5.1.2 Theoretical Underpinnings

Considering the empirical evidence pertaining to the benefits of synchronising movement to music (Anshel & Marisi, 1978; Hayakawa et al., 2000; Simpson & Karageorghis, 2006; Karageorghis et al., 2009, 2010), it is surprising that relatively little is known about the mechanisms that underpin the psychological, psychophysiological, ergogenic effects. Without sufficient understanding of how these effects come about, and how they differ from those engendered by asynchronous music, further progress in research would be severely hampered.

It has only been recently that researchers have begun to speculate on the possible processes underlying music synchrony. It has been proposed that synchronising movement patterns to an external auditory stimulus such as music could possibly lead to reduced metabolic cost; indeed it has been suggested that synchronising movement to music enhances neuromuscular or metabolic efficiency (Karageorghis, 2008; Roedink, 2008, pp. 220-221). Wilson (1986) noted that the existence of a *pacemaker* that regulates temporal function could operate by associating the afferent neural stimulus of music with a matching efferent response. Other researchers had also pointed out an attribute of the central nervous system known as *time form printing* (Clynes & Walker, 1982). This revolves around the ability of the central nervous system to utilise only the initial movement command to replicate subsequent movement patterns, thus enhancing efficiency. Nonetheless, these ideas require further empirical examination to ascertain their credibility and applicability.

As previously mentioned, matching movement to music falls under the domain of sensorimotor synchronisation. Advances in motor skill and neuroscience research have provided researchers with valuable insight into brain activation patterns during simple movement tasks under the influence of auditory synchrony. Using simple tapping task paradigms, researchers have been able to identify the neural circuitry involved with sensorimotor synchronisation (see Molinari et al., 2007, for a review). Sensorimotor synchronisation can be defined as “the basic function of producing a motor response in a time-locked fashion with a sensory rhythmic stimulus...” (Molinari et al., p. 18). Unfortunately, technology at this present time has not progressed to the point whereby brain imaging can occur in a sport or exercise setting. Fundamental physiology research has shown that an auditory stimulus can enhance spinal motor neuron excitability and subsequent motor readiness prior to supraspinal input (Paltsev & Elner, 1967; Rossignol & Melvill-Jones, 1976); a likely physiological explanation for arousal regulation via music exposure. It has also been observed that an auditory rhythm creates a point of reference which is able to attract and swiftly entrain recurring motor patterns (Rossignol & Melvill-Jones; Thaut, Miller, & Schauer, 1998). Moreover, the ability to entrain recurring patterns would indicate that the brain not only synchronises the endpoints of movement patterns to the auditory stimulus, but also the execution of the entire movement sequence (Thaut, Kenyon, Hurt, McIntosh, & Hoemberg, 2002). Thus, a rhythmic auditory stimulus (RAS) can be seen as both a primer that enhances motor corticospinal excitability and an aid providing more refined timing information to the brain, serving as an uninterrupted anticipatory time schema at any point of a movement throughout the entire duration of auditory exposure. Kenyon and Thaut (2003) proposed that by synchronising to RAS, movement patterns are optimised through an attenuation in temporal and spatial variability.

It has been observed that individuals have a preferred frequency, at least for repetitive and cyclic movements (Smoll & Schultz, 1982), and this has been identified as the resonant frequency of the muscle-limb system (Hatsopoulos & Warren, 1996). Further, Kenyon and Thaut (2003) proposed the existence of an “internal time-keeper” that plays a role in the modulation and maintenance of motor behaviour, a view shared by Wilson (1986), who referred to a pacemaker in the brain that regulates timing. Nonetheless, the precision of this internal timing mechanism has been found to vary not only among individuals, but also within an individual’s movement patterns (Smoll & Schultz). Thus, if the period of an individual’s movement varies from cycle to cycle, it is highly likely that the kinematics of the movement would also exhibit differences (Kenyon & Thaut). By providing a precise time reference, RAS acts to fine-tune an individual’s internal timing mechanism, and by extension, the kinematic parameters of the movement. More consistent and smoother movement patterns would imply a greater level of efficiency, leading to reduced metabolic cost of movement; Kenyon and Thaut termed this the *optimisation criterion*.

Employing such a criterion, Thaut and his colleagues have shown that the provision of RAS such as music or a metronome enhances patients' rehabilitation in numerous neuro-motor disorders compared to conventional therapy. Research has shown improved gait patterns, both kinematically and physiologically (EMG), for Parkinson's Disease patients (Miller, Thaut, McIntosh, & Rice, 1996; Thaut et al., 1996) and stroke sufferers (Thaut, McIntosh, & Rice, 1997). For example, Miller et al. reported that Parkinson's Disease patients that underwent a 3-week RAS therapy programme showed significant decreases in tibialis anterior and gastrocnemius shape variabilities, as well as increased gastrocnemius timing variability and reduced bilateral symmetry, profiles which more closely resemble that of normal walking gait patterns. Positive changes have also been observed for stroke patients undergoing paretic arm training (Kenyon & Thaut, 2003; Thaut et al., 2002), suggesting that synchronisation is possible for all movement patterns, not just for those inherently rhythmic in nature, such as gait.

It is entirely plausible that music synchrony in sport and exercise operates in a similar manner; ergogenic effects such as improved performance or greater endurance are due to metabolic efficiency, which in turn are a consequence of smoother kinematics. Adopting a physiological approach, Bacon et al. (2012) recently attempted to investigate the effects of synchronising music and movement on metabolic efficiency. They employed an experimental design wherein the exercise intensity and frequency of movement were fixed. By doing so, it allowed strict examination of the physiological changes that occurred with music synchrony. They speculated that at sub-maximal exercise intensities, participants maintaining a fixed cycling cadence in sync with a musical stimulus of the same tempo would exhibit improved oxygen economy. Their results indicated that the oxygen consumption of participants cycling under synchronous music and fast asynchronous music was lower when compared to a slow asynchronous music condition, indicative of an improved economy, though no logical explanation was forthcoming.

There were several methodological limitations that meant Bacon et al.'s (2012) findings should be treated with caution. First and foremost, the exclusion of a no-music control trial represented a flaw in the experimental design; it is unclear whether cycling with synchronous music affords benefits above and beyond just maintaining cadence without any external auditory (or visual) aid. Secondly, the submaximal exercise intensities were established by linear interpolation of maximal heart rate. Such a method of exercise standardisation does not give an accurate representation of one's ventilatory responses; researchers have observed that at a fixed exercise intensity of 70% aerobic capacity, different ventilatory or lactate threshold levels are exhibited by different people (Katch et al., 1978). Therefore it is unclear if such fixed percentages of peak work rate induce metabolic acidosis. Perhaps a more appropriate method of standardising exercise intensity would be to set it in relation to ventilatory threshold (T_{vent}), as this provides a more accurate indication of the contributions made by aerobic and anaerobic metabolic processes (Ekkekakis et al., 2008, 2011).

Bacon et al.'s efforts to provide some evidence of physiological changes associated with the synchronous application of music are, nevertheless, commendable and should serve as a reference point for future research in sport and exercise. Additional study is necessary, given that there is scant research and a lack of theory underlying the use of synchronous music. Moreover, there is ambiguity with regards to the potential differences between the application of synchronous versus asynchronous music. A thorough understanding of the mechanisms involved would ultimately lead to more informed decisions concerning the application of synchronous music, allowing its full potential to be harnessed.

The choice of music has always been a bone of contention for researchers engaging in synchronous and asynchronous music research. Factors such as an individual's musical preference, age, socio-cultural background, prior experiences and associations, and exposure to a range of media all play a part in determining their response to a particular musical piece (Karageorghis & Terry, 1997; Karageorghis et al., 2006; Lucaccini & Kreit, 1972). Accordingly, responses to a particular track could vary considerably across individuals. A possible solution to this selection problem is to utilise music that potential experimental participants have had no prior exposure to. Although this alternative does not negate all of the above factors, it does minimise to a large extent the influence of prior experiences, associations, and media exposure.

5.1.3 Rationale

The rationale for the present study is multi-faceted. First, there is a paucity of research comparing the effects of asynchronous music versus synchronous music. This makes it difficult to advance research in both asynchronous and synchronous music as it is unclear, at least empirically, if there should be a demarcation between them in the first place. Further, the present study seeks to determine if the proposed theoretical concept, *optimisation criterion*, was a viable explanation for the ergogenic benefits of auditory synchrony, by investigating a range of physiological responses that may lead to metabolic efficiency. Oxygen uptake was chosen as the independent variable because of two important reasons: (a) it has been observed previously by Bacon et al. (2012) to be positively affected by music; and (b) possible influences from psychological factors such as motivation and affect would be negligible on $\dot{V}O_2$ (Schücker, Hagemann, Strauss, & Völker, 2009).

5.1.4 Purpose

The main purpose of the present study was to investigate the physiological, psychophysical, and psychological effects of a metronome, asynchronous and synchronous music on a submaximal cycle ergometer task. Adopting the *optimisation criterion* as the main theoretical reference point, it was hypothesised that participants (a) pedalling in time with synchronous music and a metronome would be kinematically more efficient, resulting in lower $\dot{V}O_2$, when compared to asynchronous music and a no-auditory control; (b) would derive greater pleasure and higher levels of arousal from both music conditions as opposed to the metronome and control conditions due to their aesthetic properties; and (c) cycling with any kind of auditory stimuli would result in lower levels of perceived exertion in comparison to control because of the associated distractive qualities. Given the lack of empirical evidence, it is presently unclear whether any psychological differences would be found between the two music conditions, and whether perceived exertion would be affected similarly across the three experimental conditions. Therefore the null hypothesis was tested in these instances.

5.2 Method

5.2.1 Piloting

A consultation was arranged with a psycho-musicologist to determine the choice of music for the experiment. Run2Rhythm, an online Australian-based company, was chosen to provide the music for the study as they specialise in original music compositions for specific use in sport and exercise. A total of 15 tracks, ranging from 150-171 bpm, was provided, and of these, only those below 160 bpm (*k* = 7) were selected as potential choices due to their proximity to the cycling cadence to be employed in the experimental phase. Following extensive discussion and review of the remaining tracks, two were selected based on their rhythmic qualities and similarities to currently popular music genres. Relevant details of the tracks would be described later.

Pilot work was conducted to determine the feasibility of the intended experimental protocol and procedures, as well as to address any potential problems that might arise. Initial testing revealed that it was particularly difficult for participants to synchronise their pedalling rate to the beat of an auditory stimulus, whilst visually monitoring the cadence display. Accordingly, it was decided that the visual display would only be made available for conditions that did not include a marker of time (i.e., asynchronous music and no-music control). Further, it was established during piloting that participants were able to synchronise their pedalling rate swiftly and accurately to the prescribed cadence without any difficulty. Thus one habituation session was deemed necessary to familiarise participants to the nature of the task.

5.2.2 Power Analysis

An appropriate sample size for the experimental phase was determined using a power analysis software program (G*Power 3.1.2; Dusseldorf University, Dusseldorf, Germany). Alpha was set at .05, power at .8 to protect beta at four times the level of alpha (Cohen, 1988). A conservative estimate of .5 was selected for the inter-correlation between repeated measures, while the non-sphericity correction entered was 1. Using an estimation of a moderate effect size (*f* = .25) to detect the effects of synchronous music (Bacon et al., 2012; Simpson & Karageorghis, 2006), it was determined that 24 participants would be required for the study.

5.2.3 Participants Characteristics

A convenience sample of 24 recreationally active males (M_{age} = 22.0 years, M_{weight} = 74.2 kg, M_{height} = 178.8 cm) were recruited from the undergraduate and postgraduate body of students at Brunel university. All levels of cycling ability were accepted as this would not have an impact on results due to the repeated measures nature of the experimental design. Females were not recruited as it was deemed that the menstrual cycle might have a confounding influence on the results; some mood states have been found to vary in accordance with the menstrual cycle. Thus potential benefits of music might be obscured with a female population (Reilly et al., 1996). Moreover, there were ethical issues surrounding a male researcher questioning female participants on details relating to their menstrual cycle.

Prior to the start of the first session, participants filled out a general health questionnaire (Appendix D) and gave written consent (Appendix A). They were informed that they could withdraw from the study at any time without penalty or consequence. Each participant's height (cm) and body mass (kg) were measured using a stadiometer and calibrated electronic scales respectively (Seca 220; Seca Limited, Birmingham, UK).

5.2.4 Apparatus and Instrumentation

5.2.4.1 Cycle ergometer. An electromagnetically-braked cycle ergometer (Velotron; RacerMate Inc., Seattle, Washington, USA) was used for the determination of maximal oxygen uptake as well as for the main exercise tasks. The Velotron utilises a patented electromagnetic braking system around a large, hefty diameter flywheel to regulate resistance. Prior to each testing session, the Velotron's in-built *Accuwatt* calibration checking procedure was carried out to verify no deviations from the original factory performance. Relevant data were continuously recorded and stored for every session through computer-controlled software (Velotron Coaching Software, Version 1.50; RacerMate Inc., Seattle, Washington, USA). Saddle and handlebar configurations were adjusted to each participant's requirements before commencement of any tests, and the same configurations were used throughout both sessions.

5.2.4.2 Auditory stimulus. Two music tracks were selected: *I Fly In My Dreams* (156 bpm), and *The Power Of Sound* (156 bpm), both by composer Andrew Batterham. The chosen tracks were produced by Run2Rhythm (www.run2r.com), an Australian company that specialises in original music compositions specifically for synchronous music accompaniment to exercise. Although the compositions were composed with running in mind, they can be easily applied to a wide range of synchronous exercise modalities, including cycling. The underlying rationale for this choice of music concerns its relative obscurity among British music listeners; this minimised the influence of factors such as socio-cultural background, age and musical preferences, all of which have been reported to have an influence on how music is perceived and processed (Karageorghis et al., 1999; North & Hargreaves, 1997; North et al., 2004). Moreover, elements such as extra-musical associations and cultural impact were negligible due to unfamiliarity. All potential participants were screened beforehand to ensure they had no prior knowledge about the musical selection or the company Run2Rhythm.

After consultation and piloting, it was decided that *I Fly In My Dreams* (156 bpm) would be used for the main experimental sessions, whilst *The Power Of Sound* (156 bpm) was chosen for the familiarisation; the decision was based on the former track having a more prominent beat. The tempi of tracks were digitally altered without distorting the other musical qualities using audio editing software (Audacity;

audacity.sourceforge.net). The experimental track had two variants, 150 bpm (synchronous condition), and 170 bpm (asynchronous condition), whilst the familiarisation track had the tempo altered to 150 bpm. An auditory metronomic ticking tone of 150 bpm was created using specialised software (TempoPerfect Metronome Software; NCH Software Pty Ltd, Canberra, Australia). Auditory stimuli were delivered via loudspeakers and a decibel meter (AZ 8928; AZ Instrument Corporation, Taichung City, Taiwan) was used to standardise sound intensity at 80 dBA; this volume lies within the safe limits from an audiological perspective (see Alessio & Hutchinson, 1991). The playlist was stored in a computer laptop and delivered via speakers located at the rear of the laboratory.

5.2.4.3 Physiological measures.

5.2.4.3.1 Respiratory assessment. Respiratory variables were recorded via a breath-by-breath online gas analyser system (Quark b^2, Cosmed, Rome, Italy). Inspired and expired volumes were assessed by a digital turbine transducer that had a low resistance to airflow ($< .7\ \text{cmH}_2\text{O}\cdot\text{l}^{-1}\cdot\text{s}^{-1}$ at $12\ \text{l}\cdot\text{s}^{-1}$). The transducer operates by air passing through the helical conveyors in a spiral motion, resulting in the rotation of the turbine rotor. The rotating blades of the turbine interrupt infrared light beamed by three diodes within an optoelectronic reader; each interruption corresponds to 1/6 turn of the rotor. This allows the number of turns in a specific timeframe to be determined. A consistent ratio exists between air passing through the turbine and time, allowing precise measurements of flow and hence, volume. The turbine was calibrated for flow and volume using a 3 L syringe before each testing session in accordance with the manufacturer’s instructions.

Pulmonary gas exchange was assessed by continuously sampling expired air at the mouth using a Nafion Premapure® sampling line. Concentration levels of O_2 and

CO_2 were analysed from the sampled air via a Zirconia temperature controlled O_2 analyser (range = 1 – 100% O_2) and a non-dispersive infrared CO_2 analyser (range = 0-15% CO_2), both of which have a response time of < 120 ms. Prior to each testing session, both analysers were calibrated using certified gas mixtures (16% O_2, 5% CO_2 and N_2 balance). Inspiratory and expiratory times (T_I and T_E), expired tidal volume (V_T), respiratory frequency (f_R), expired minute ventilation ($\dot{V}_E$), end-tidal partial pressure of O_2 (P_{ETO2}), end-tidal partial pressure CO_2 (P_{ETCO2}), oxygen uptake ($\dot{V}O_2$), and carbon dioxide output ($\dot{V}CO_2$) were the respiratory variables measured.

5.2.4.3.2 Heart rate. Participants’ heart rate was continuously monitored at a 5 s sampling rate using a chest strap transmitter linked to a wristwatch (Polar S610i; Polar Electro Oy, Kempele, Finland). At the end of every testing session, the data were uploaded onto a computer containing heart rate data management software (Polar Precision Performance SW; Polar Electro Oy, Kempele, Finland).

5.2.4.4 Psychophysical and psychological instrumentation.

5.2.4.4.1 Ratings of perceived exertion. Participants’ perception of exertion was measured using the Category Ratio 10 scale (CR10; Borg, 1998). The scale ranges from 0 (*nothing at all*) to 10 (*very very hard*), followed by a dot denoting maximal exertion. There are several verbal descriptors anchored alongside certain numbers that relate to psycho-physiological perceptions of effort. The CR10 scale has demonstrated high validity in terms of its correlations with common physiological indices (r = .80 to .95; Borg). High intratest (r = .93) and retest (r =.83 to .94) reliability were also observed for the scale. Participants were required to give two RPE ratings: Central and peripheral. Central RPE was concerned with respiratory exertion, whereas peripheral RPE referred to lower limb exertion. They were instructed to use their index finger to indicate their ratings on an enlarged RPE scale flashed by the experimenter.

Before the start of each testing session, participants were provided with a written description of perceived exertion and instructions on how to use the CR10 scale. They were then requested by the researcher to recall past experiences of perceived exertion that could be anchored to the bottom and top of the scale (i.e., at 0 and 10), in order to obtain an understanding of how to make their responses. For levels of exertion greater than 10, participants were told to give an appropriate number that corresponds to the effort. Participants were also told that responses given should be spontaneous and specific to their subjective feelings of the level of exertion (Borg, 1998).

5.2.4.4.2 In-task affective valence and arousal. In-task affective valence was assessed with reference to the circumplex model, using Rejeski's (1985) Feeling Scale (FS). It is an 11-point, single-item measure, with a scale ranging from -5 to +5. Descriptive markers are provided at zero (*Neutral*), and at all odd integers, ranging from *Very Bad* (-5) to *Very Good* (+5). The FS has shown correlations between .51 and .88 with the valence scale of the Self-assessment Manikin (SAM; Lang, 1980), and from .41 to .59 with the valence scale of the Affect Grid (AG; Russell, Weiss, & Mendelsohn, 1989). According to Ekkekakis and Petruzzello (2002), the FS is a suitable and valid in-task affect measurement instrument, particularly because it limits respondent overload, appropriate for repeated assessments during exercise.

Arousal was measured using the Felt Arousal Scale (FAS) of the Telic State Measure (Svebak & Murgatroyd, 1985). It is a six-point, single-item measure with a scale from 1 to 6. Anchors are provided at 1 (Low Arousal) and 6 (High Arousal).

The FAS has exhibited correlations between .45 and .70 with the arousal scale of the SAM and .47 to .65 with the Arousal scale of the AG.

5.2.5 Experimental Design

Participants visited the laboratory on two occasions that were separated by at least 48 hr. The purpose of the first visit was twofold: 1) to establish participants' ventilatory threshold and maximal oxygen uptake ($\dot{V}O_{2max}$); and 2) to familiarise them with the cycle ergometer and exercise protocol. The level of exercise intensity was set in relation to the T_{vent}, which is considered to be a more robust method of standardising relative workload. An exercise intensity of 90% T_{vent} was chosen as this workload was considered to be submaximal. Altareki et al. (2006) found that at least one familiarisation session was required to reduce the possible influence of learning effects with the use of the CompuTrainer ergometer. Although the cycle ergometer used in the current study was the Velotron, the results obtained by Altareki et al. were applicable as the two ergometers are made by the same company and serve almost identical purposes. This session also served to acquaint participants with the various psychological and psychophysical instruments that were to be administered during the experimental phase.

The second visit comprised the experimental phase. Four conditions were administered to participants: 1) No-music control; 2) synchronous metronome (150 bpm); 3) synchronous music (150 bpm); and 4) asynchronous music (170 bpm). The inclusion of a no-music condition served as a basis for comparison, whilst the metronome allowed for the examination of the effects of tempo independent of musical qualities such as harmony and melody. The synchronous music condition allowed researchers to assess the effects of tempo and those associated with other qualities of music, whereas the asynchronous music condition provided an opportunity to measure changes induced by musical factors independent of keeping in sync with music tempo. This not only allows the examination of the possible effects resulting from smoother movement kinematics via RAS, but also potential benefits that could be derived from exposure to other musical qualities other than tempo, as proposed by Karageorghis et al.'s (1999) asynchronous music framework. Participants were to maintain a cycling cadence of 75 rpm throughout each exercise bout; a full pedal revolution occurring regularly at 75 rpm can be performed in synchrony with a tempo of 150 bpm, with a semi-revolution of the pedals per beat.

To ensure the accuracy of respiratory responses, gas collection had to occur under steady state exercise conditions. During steady state exercise below T_{vent}, $\dot{V}CO_2$ has been reported to take at least 4 min to reach steady state (Wasserman, Hansen, Sue, Stinger, & Whipp, 2005). Although previous research of a similar nature (Bacon et al., 2012) had used an exercise period of 20 min, researchers have suggested exercise durations of at least 5 min when obtaining gas-exchange data for the calculation of efficiency (Hopker et al., 2009). Accordingly, it was decided that an exercise duration of 6 min would suffice for the purpose of the present investigation, given the exercise intensity was set at a submaximal intensity of 90% T_{vent}. Thus, participants were required to complete four 6-min cycling bouts in total, with a rest period of 6 min prior to the start of each exercise bout.

5.2.6 Procedures

5.2.6.1 Maximal oxygen uptake and familiarisation. An incremental ramp test was conducted to determine participants' maximal oxygen uptake ($\dot{V}O_{2max}$). Participants pedalled for 3 min at 30 W as a warm-up, after which there was a linear increase of 30 W/min up to the point of exhaustion. Exercise termination was taken as the point at which participants were unable to maintain a cycling cadence of 75 rpm for more than 10 s. Breath-by-breath pulmonary gas exchange data were recorded continuously during the incremental task and averaged over 10 s periods. Maximal oxygen uptake was determined as the highest 30 s average value attained by the participant prior to termination of the incremental test.

To ensure that the $\dot{V}O_{2max}$ obtained in the incremental ramp protocol was indeed a true reflection of maximal oxygen uptake, an appended step test was conducted after a 10-15 min rest period (Day, Rossiter, Coats, Skasick, & Whipp, 2003; Rossiter, Kowalchuk, & Whipp, 2005). Participants cycled at 30 W for about 10 s, after which there was an abrupt transition to a workload corresponding to 5% above the maximum wattage achieved in the incremental test. As before, the appended step test was concluded when participants' pedal cadence dropped below 75 rpm for more than 3s. The highest 30 s average of $\dot{V}O_{2max}$ between the incremental test and appended step test was taken as the maximal value. Ventilatory threshold was determined from several gas exchange indices: 1) a disproportionate rise in CO_2 output from visual inspection of individual plots of $\dot{V}CO_2$ vs. $\dot{V}O_2$; 2) an increase in expired minute ventilation ($\dot{V}_E$/ $\dot{V}O_2$) without a corresponding rise in $\dot{V}_E$/ $\dot{V}CO_2$; and 3) a rise in P_{ETO2} absent of a corresponding decline in P_{ETCO2} (Wasserman et al., 2005). The workload for the experimental trial (i.e., 90% T_{vent}) was determined from the data obtained in the incremental test; it was calculated with consideration taken for the mean response time for $\dot{V}O_2$ during ramp exercise (i.e., 2/3 of the ramp rate was subtracted from the work rate at T_{vent}; Whipp, Davis, Torres, & Wasserman, 1981).

Following the appended step test and a subsequent rest period of 10 min, participants were familiarised to the experimental task by having their pedal cadence synchronised to the track previously chosen for this purpose. They were also introduced to the psychophysical and psychological measurements and related administration protocols.

5.2.6.2 Experimental phase. At least 48 hr and a maximum of seven days separated the initial visit from the experimental session. During the experimental visit, participants cycled at an exercise intensity of 90% T_{vent} (moderate-intensity), while maintaining a pedal cadence of 75 rpm, for 6 min, under each of four conditions. This was repeated until every condition had been completed. In the no-music control and asynchronous music conditions, participants maintained the prescribed pedal rate via a computer screen that displayed visual information on cycling cadence. For the synchronous music and metronome conditions, participants were instructed to use the beats of the relevant auditory stimulus to maintain their pedal frequency. No visual feedback was provided in these instances, as pilot work revealed that presenting both visual and auditory sources of information could cause confusion for participants. The pedal cadence was continuously recorded for every exercise bout, and also monitored by the lead researcher to ensure any major deviations (± 2 rpm) from the prescribed cadence were immediately corrected. Respiratory data and heart rate was continuously recorded for the entire duration of each bout via the online gas analyser system and radio-telemetry respectively. Participants provided responses for breathing exertion, leg exertion, in-task affective valence, and arousal at 2 min intervals throughout the exercise by pointing to an appropriate number on the respective scales. Affective valence and arousal were also assessed prior to and after each exercise bout.

To minimise learning effects, the order of conditions undertaken by each participant was randomly assigned and fully counterbalanced. Potential confounding variables such as temperature and humidity were monitored before the start of each visit. Participants were asked to refrain from any form of vigorous physical exercise for 48 hr prior to testing. They were also instructed not to consume products containing caffeine or food and drinks (except water) 12 hours and 3 hours respectively, prior to each visit.

5.2.7 Data Analysis

Data for $\dot{V}O_2$ and heart rate were collected continuously for the entire 6-min task duration. However, only the last 1 min was used in the analysis as it was considered to be an accurate reflection of steady state condition (see Wasserman et al., 2005). The values were averaged out over the last min to give an overall mean. In the case of RPE, in-task affective valence and arousal, these variables were measured at three intervals: 2, 4, and 6 min. Again, the data for each variable were collated to give an average value. The averaging of data was carried out as the interest of the study was in the global effects of the experimental conditions.

Raw data were screened for univariate outliers using standardised scores ($-3.29 \leq z \geq 3.29$), and, where relevant, the Mahalanobis distance method with $p < .001$ was used to identify multivariate outliers (Tabachnick & Fidell, 2007, p. 73). These procedures were carried out for each separate analysis and for each cell within each analysis. Further, standard skewness and kurtosis were examined in each cell of each analysis to check for deviations from normality (Std. Skew/Kurt.≥ 1.96; Vincent, 2005, p. 89). Tests were also carried out to ensure the data met the relevant parametric assumptions. All dependent variables were analysed using one-way repeated-measures ANOVA with Bonferroni adjustments. Where necessary, univariate tests were corrected for sphericity violations using Greenhouse-Geisser adjusted *F* values. Analyses were performed using SPSS for Windows Version 15 (SPSS, Inc., Chicago, IL).

5.3 Results

A total of 24 participants were recruited for the study, but only 23 participants completed the entire experiment as one participant withdrew after the first visit. No univariate or multivariate outliers were identified for any variable during the data screening process. Although there was a violation of normality for limb RPE (std. skew. 2.01), the value is relatively minor and did not warrant the transformation of the data set. Descriptive statistics, and standard skewness and kurtosis for each dependent variable are presented in Table 5.1. The specific details of each analysis will be covered in the subsequent sections.

5.3.1 Oxygen Uptake

Data screening revealed no univariate outliers, and tests of standard skewness and kurtosis indicated that there were no violations of normality. Given that all of the parametric assumptions were met, the F test was retained as the test of significance. Mauchly's Test of Sphericity revealed no violation for the assumption of sphericity ($W = .829$, $\varepsilon = .905$, $p = .57$). The condition effect was non significant, $F(3, 66) = .76$, $p = .523$, $\eta_p^2 = .03$, and this accounted for just 3% of the overall variance. The provision of any form of auditory stimulus did not affect $\dot{V}O_2$; mean oxygen uptake was similar across all four conditions (Figure 5.1).

Table 5.1

Descriptive Statistics, Standard Skewness and Kurtosis for all Dependent Variables

Dependent Variable	Condition	*M*	*SD*	Std. Skew.	Std. Kurt.
$\dot{V}O_2$ (ml/min/kg)	Control	23.63	4.60	.02	1.40
	Metronome	23.44	4.61	.34	1.40
	Sync. Music	23.51	4.65	-.29	1.26
	Async. Music	23.50	4.80	.14	1.36
Heart Rate (bpm)	Control	125.90	16.65	-.50	-.82
	Metronome	122.53	15.82	-.89	-.35
	Sync. Music	123.79	15.89	-.58	-.55
	Async. Music	125.4	16.88	-.56	-.59
Respiratory RPE	Control	2.22	1.04	.26	.23
	Metronome	2.01	1.09	1.63	1.94
	Sync. Music	2.02	1.11	1.76	1.53
	Async. Music	2.06	1.19	.71	-.05
Muscular RPE	Control	2.95	1.53	2.01*	1.56
	Metronome	2.50	1.20	.05	-.48
	Sync. Music	2.26	1.13	.40	.09
	Async. Music	2.48	1.46	1.19	-.06
In-task Valence	Control	1.16	1.25	-.30	-.89
	Metronome	1.18	1.41	-.01	-1.25
	Sync. Music	1.91	1.15	-.27	-1.05
	Async. Music	2.09	1.30	.16	-1.36
In-task Arousal	Control	2.82	.94	-.43	-.24
	Metronome	2.83	1.00	.63	.40
	Sync. Music	3.44	.91	-1.55	1.10
	Async. Music	3.25	1.10	.69	.06

* $p < .05$.

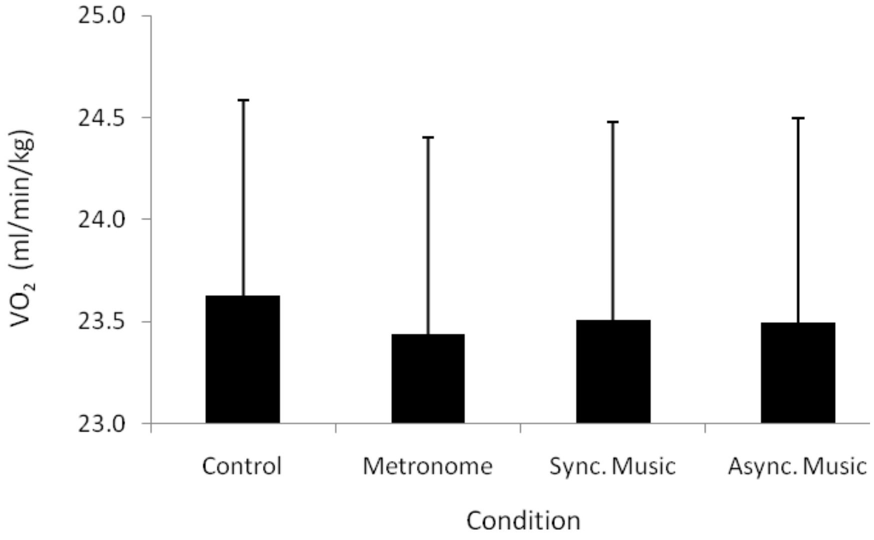

Figure 5.1. Means and standard errors (T-bars) for $\dot{V}O_2$ under conditions of control, metronome, synchronous music, and asynchronous music.

Note. Asterisk denotes significant difference (*p* < .05).

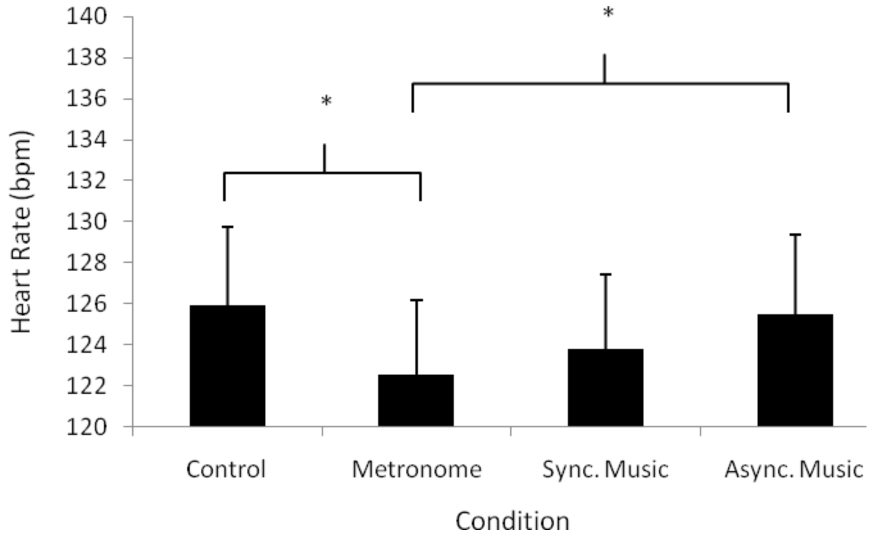

Figure 5.2. Means and standard errors (T-bars) for heart rate under conditions of control, metronome, synchronous music, and asynchronous music.

Note. Asterisk denotes significant difference (*p* < .05).

5.3.2 Heart Rate

A total of four participants were excluded from the data set as their heart rate responses were inconsistent. Data screening revealed no univariate outliers, and tests of standard skewness and kurtosis indicated that there were no violations of normality. Given that all of the parametric assumptions were met, the *F* test was retained as the test of significance. Mauchly's Test of Sphericity revealed no violation for the assumption of sphericity ($W = .833$, $\varepsilon = .896$, $p = .61$).

The condition effect was significant, $F(3, 54) = 4.01$, $p = .012$, $\eta_p^2 = .18$, and this accounted for 18% of the variance. Follow-up pairwise comparisons with Bonferroni adjustment indicated that heart rate was significantly lower in the metronome condition compared to asynchronous music ($p = .03$, $M = -2.64$ bpm, 95% CI = [-5.06, -.21]) and no-music control ($p = .01$, $M = -3.59$ bpm, 95% C. I. = [-6.53, -.65]), though no significant differences in heart rate were observed between metronome and synchronous music ($p > .05$). There were also no significant differences across the remaining three conditions (Figure 5.2).

5.3.3 Ratings of Perceived Exertion

Data screening revealed no univariate or multivariate outliers. Tests of standard skewness and kurtosis indicated that there were minor violations of normality; minor positive skewness was reported for limb RPE for no-music control (see Table 5.1). Nonetheless, the violations were not due to outliers (Tabachnick & Fidell, 2007, p. 78), and violations of the ANOVA assumption of normality do not drastically affect the *F* value (Vincent, 2005, p. 163). Given that all of the parametric assumptions were met, the *F* test was retained as the test of significance. Mauchly's Test of Sphericity revealed no violation for the assumption of sphericity ($W_{\text{central}} = .942$, $\varepsilon = .962$, $p = .94$, $W_{\text{peripheral}} = .594$, $\varepsilon = .729$, $p = .06$).

5.3.3.1 Central RPE. The condition effect was non significant, $F(3, 66) = 1.38$, $p = .255$, $\eta_p^2 = .06$, and this accounted for 6% of the variance. Ratings were similar across all conditions (Figure 5.3).

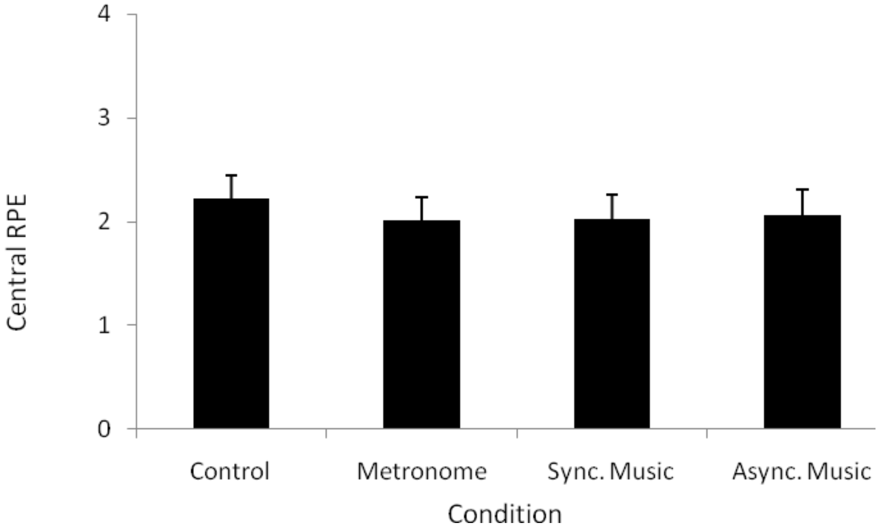

Figure 5.3. Means and standard errors (T-bars) for central RPE under conditions of control, metronome, synchronous music, and asynchronous music.

Note. Asterisk denotes significant difference ($p < .05$).

6.3.3.2 Peripheral RPE. The condition effect was significant, $F(3, 66) = 5.93$, $p = .001$, $\eta_p^2 = .21$, and this accounted for 21% of the variance, representing a large effect. Follow-up pairwise comparisons with Bonferroni adjustment indicated that participants in the control condition were reporting significantly higher peripheral RPE when compared against the metronome ($p = .01$, $M = .47$, 95% CI = [.09, .84]) and synchronous music conditions ($p = .01$, $M = .70$, 95% CI = [.13, 1.27]). There were no significant differences for asynchronous music compared to all other conditions, and there were also no differences observed between the metronome and synchronous music condition (Figure 5.4).

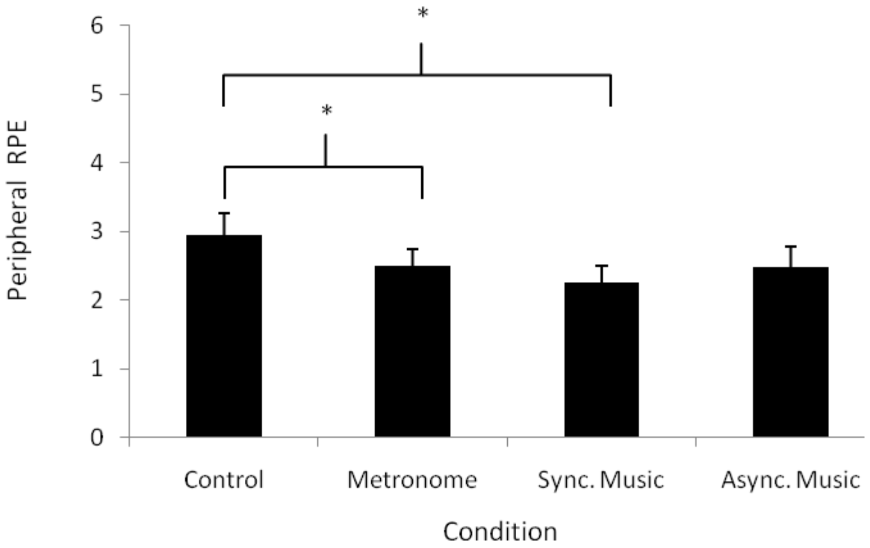

Figure 5.4. Means and standard errors (T-bars) for peripheral RPE under conditions of control, metronome, synchronous music, and asynchronous music.

Note. Asterisk denotes significant difference ($p < .05$).

5.3.4 Psychological Responses

Data screening revealed no univariate or multivariate outliers, and tests of standard skewness and kurtosis indicated that there were no violations of normality. Given that all of the parametric assumptions were met, the *F* test was retained as the test of significance. Mauchly's Test of Sphericity revealed no violation for the assumption of sphericity ($W_{\text{affect}} = .784$, $\varepsilon = .886$, $p = .41$, $W_{\text{arousal}} = .869$, $\varepsilon = .915$, $p = .71$).

6.3.4.1 In-task affective valence. The condition effect was significant, $F(3, 66) = 9.51$, $p < .001$, $\eta_p^2 = .30$, and this accounted for 30% of the variance, representing a large effect. Follow-up pairwise comparisons with Bonferroni adjustment indicated that in-task affective valence was significantly higher for both music conditions compared to the metronome ($p_{\text{sync}} = .01$, $M = .74$, 95% CI = [.16, 1.32], $p_{\text{async}} = .01$, $M = .93$, 95% CI = [.24, 1.62]) and no-music control ($p_{\text{sync}} = .004$, *M* = .74, 95% CI = [.20, 1.28], p_{async} = .01, *M*= .94, 95% CI = [.20, 1.67]). Further there were no differences between both music conditions, as well as between metronome and no-music control conditions (Figure 5.5).

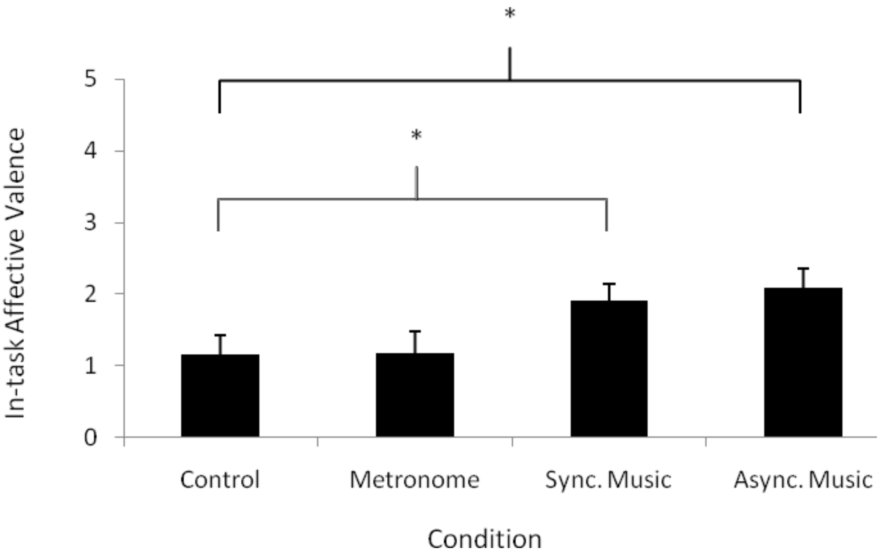

Figure 5.5. Means and standard errors (T-bars) for in-task affective valence under conditions of control, metronome, synchronous music, and asynchronous music. *Note*. Asterisk denotes significant difference ($p < .05$).

6.3.4.2 In-task arousal. The condition effect was significant, *F*(3, 66) = 4.78, *p* = .004, η_p^2 = .18, and this accounted for 18% of the variance, representing a moderate effect. Follow-up pairwise comparisons with Bonferroni adjustment indicated that arousal was significantly higher in the synchronous music condition when compared against both metronome (*p* = .01, *M* = .61, 95% CI = [.12, 1.10]) and no-music control (*p* = .03, *M* = .63, 95% CI = [.06, 1.20]). There were no differences for asynchronous music when compared to the other three conditions (Figure 5.6).

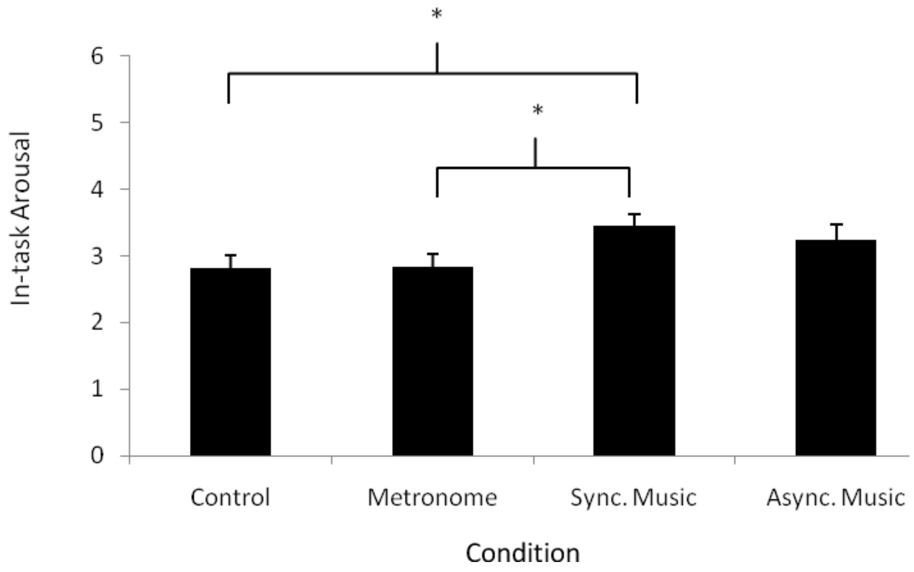

Figure 5.6. Means and standard errors (T-bars) for in-task arousal under conditions of control, metronome, synchronous music, and asynchronous music.

Note. Asterisk denotes significant difference (*p* < .05).

5.4 Discussion

The aim of the present study was to examine the psychological, psychophysical, and physiological effects of asynchronous and synchronous music on a submaximal cycle ergometer task. It was hypothesised that: (a) Participant listening to synchronous music and a metronome would exhibit greater oxygen economy, when compared to asynchronous music and a no-music control; (b) participants will derive greater pleasure and higher levels of arousal from both music conditions when compared against the metronome and control conditions; and (c) participants cycling under any form of auditory stimulus would result in lower levels of perceived exertion in comparison to no-music control.

In terms of physiological response, $\dot{V}O_2$ did not differ significantly across conditions, but a significant effect was reported for heart rate. Participants cycling under the metronome condition exhibited heart rate levels that were lower when compared against both asynchronous music and the no-music control conditions.

Thus, hypothesis (a) is only partly supported. For psychophysical responses, there were significant differences in peripheral, but not central RPE across conditions. Psychological effects also emerged with significant differences for both in-task affective valence and felt arousal. Therefore hypotheses (b) and (c) were not rejected. Overall, the findings of the present research seem to indicate that synchronous and asynchronous music affect individuals differently, and cycling to an RAS has potential to reduce metabolic cost.

5.4.1 Oxygen Uptake and Heart Rate

In the present study, participants synchronising their movement to an RAS did not engender greater oxygen economy when compared to cycling under the asynchronous music and no-music control conditions. This finding is in contrast to those reported in a similar study by Bacon et al. (2012); they found that $\dot{V}O_2$ was significantly lower with synchronous and fast asynchronous music when compared against slow asynchronous music. Nonetheless, experimental design flaws inherent in Bacon et al.’s study meant that their findings should be treated with caution. The current observation would suggest that auditory-motor synchronisation does not lead to reduced oxygen cost, and thus the *optimisation criterion* might not be a tenable hypothesis with reference to the ergogenic effects of synchronous music.

Interestingly, there was a significant main effect for condition on heart rate: Participants cycling to a metronome had significantly lower heart rates compared against cycling under asynchronous music and no-music control conditions, but no differences were observed for synchronous music in comparison to the other three conditions. Such an observation would suggest that some form of auditory-motor synchronisation could possibly influence metabolic efficiency, lending support to the idea of an *optimisation criterion*. It is entirely plausible that this efficiency is a reflection of other physiological processes that are distinct from oxygen uptake.

One such process is the recruitment of motor neurons, which is traditionally investigated non-invasively via EMG. Indeed, Thaut and colleagues have shown that the provision of RAS (either music or a metronome) reduces the variability of timing and the magnitude of EMG in gait patterns of patients suffering from Parkinson’s disease (Miller et al., 1996; Thaut, 1997; Thaut et al., 1996, 1997) and hemiparetic stroke (Thaut et al., 1997). These reductions in EMG profiles indicate that timing movement to RAS results in more consistent and efficient motor neuron recruitment. Moreover, Safranek, Koshland, and Raymond (1982) observed that healthy female participants performing an arm movement task under a rhythmic stimulus recorded less variability in EMG activity when compared to an uneven rhythm and no auditory stimulus. Taken collectively, empirical research findings would suggest that decreased variability in EMG patterns is not solely restricted to patients suffering from neuromuscular disorders, but is also exhibited by healthy participants.

Given the results of the aforementioned studies, it is speculated that in the present study the lower heart rates observed under metronomic regulation were due to more efficient recruitment of motor units. Accordingly, the notion of an *optimisation criterion* remains a valid hypothesis for explaining the processes underlying the effects of synchronous music use. Nonetheless, EMG was not assessed in the present study, making it difficult to attribute lower heart rates to more efficient motor neuron recruitment.

Given that the metronome condition induced changes in heart rate, one would also expect similar changes in response to synchronous music, since both operate as timing references. There are two possible reasons accounting for why synchronous music did not have the same effect as the metronome on heart rate. Firstly, there is a likelihood that participants cycling to the metronome were able to identify the beat more easily compared to synchronous music, due to the additional qualities of melody and harmony. This, however, is unlikely as participants in both conditions were equally able to maintain the prescribed cadence without difficulty. The other, more plausible explanation as to why participants in the synchronous music condition did not exhibit reduced heart rates may be due to the musical qualities; these qualities significantly aroused participants, leading to elevations in heart rate. Thus any possible reductions in heart rate that might result from synchronisation with the tempo of the music might have been masked by the elevations caused by the other musical qualities.

The lack of any significant changes in oxygen consumption is surprising, given that reductions in heart rate were observed when participants cycled under metronomic regulation. One plausible reason for this observation could be that respiratory variables require more time to respond to the experimental intervention. It is quite possible cardiovascular variables are affected almost instantly, and that these instantaneous changes in heart rate require some time to filter through to $\dot{V}O_2$. It is noteworthy that responses in the present study were only measured for the last minute of each exercise bout, and may have been insufficient to reflect any changes in $\dot{V}O_{2.}$ Previous research that reported more efficient oxygen economy subjected participants to exercise durations of more than 3 min (e.g., Bacon et al., 2012; Terry et al., 2012). Thus, extending the exercise duration for a longer period might allow any significant changes in $\dot{V}O_2$ to materialise.

5.4.2 Perceived Exertion

Current findings indicate that auditory synchronisation affect central and peripheral RPE differently. The lack of a main effect of condition on central RPE would suggest that the provision of an auditory stimulus and/or synchronisation do not influence the perception of respiratory effort. This finding is amplified by the nonsignificant findings for $\dot{V}O_2$.

Results for peripheral RPE paint a difference picture; participants under auditory synchronisation reported significantly less fatigue in their lower extremities compared to cycling in the no-music control condition. No significant differences were observed between both auditory synchrony conditions, although the lowest scores were reported while exercising to synchronous music. In addition, perceptions of fatigue during asynchronous music exposure did not differ from the other conditions, possibly indicating that asynchronous music did alter participants' perceived effort, but that its effects were not as strong as those engendered by auditory synchronisation.

Taken together, the current findings on both components of RPE strongly indicate that the effects of synchronisation are more efficacious in diverting fatigue away from focal awareness than the other qualities of music such as melody and harmony, at least for a 6 min exercise bout. Although reductions in muscular exertion were also reported by participants while listening to asynchronous music, peripheral RPE was not significantly different ($p > .05$) from the no-music control condition. Karageorghis et al. (2009) suggested that synchronising movement to RAS is a form of active attentional manipulation that enhances the effects of music listening on RPE, which is a passive attentional manipulation. Thus it appears that active and passive attentional manipulations can have an additive effect when employed together, but musical properties such as harmony and melody appear to affect RPE to a lesser degree when compared to auditory synchronisation.

The effects of music on RPE have mostly been investigated through the asynchronous application of music; early studies have shown that reductions in perceived exertion are only evident during submaximal exercise (e.g., Copeland & Franks, 1991; Nethery, 2002; Potteiger, Schroeder, & Goff, 2000; Szmedra & Bacharach, 1998), and music is ineffective in diverting attention at higher intensities or exercise to exhaustion tasks (e.g., Boutcher & Trenske, 1990; Elliot et al., 2005; Schwartz et al., 1990; Tenenbaum et al., 2004). However, more recent research has contradicted this RPE-exercise intensity relationship: Miller, Swank, Manire, Robertson, and Wheeler (2010) had participants running for 20 min at 75-85% $\dot{V}O_{2max}$, under conditions of self-chosen music and a control condition that consists of verbal dialogues. Lower perceived exertion was reported under music influence, suggesting that the efficacy of external distractive strategies might not necessarily be constricted by high workloads. Nonetheless, researchers (e.g., Ekkekakis et al., 2008, 2011; Katch et al., 1978) have pointed out that setting exercise intensity in relation to heart rate or aerobic capacity does not accurately reflect the balance of metabolic processes. Accordingly, the “high” workloads employed in previous studies (e.g., Boutcher & Trenske; Elliot et al.; Miller et al.; Schwartz et al.; Tenenbaum et al.) may still be considered to be at submaximal intensity. Interestingly, the music used in those studies that reported reductions in RPE (e.g., Copeland & Franks; Miller et al.; Nethery; Potteiger et al.; Szmedra & Bacharach) was not chosen based on the motivational qualities outlined by Karageorghis et al. (1999), possibly indicating that these qualities may play a limited role in affecting psychophysical responses during exercise.

It is quite possible that the effects of asynchronous music on RPE require longer exercise durations to yield benefits; the aforementioned studies typically utilised exercise protocols that lasted longer than the 6 min of the current study. From a physiological perspective, fatigue should have a positive linear relationship with exercise duration, even at submaximal intensities. Thus, the longer an exercise bout, the more fatigue an individual is likely to experience. There might be a fatigue threshold over which asynchronous music exerts its effects on RPE.

5.4.3 Psychological Response

Both music conditions elicited greater feelings of pleasure compared to metronome and no-music control conditions, while no differences were noticed between the metronome and control conditions. This is in line with existing literature on both asynchronous music (Boutcher & Trenske, 1990; Elliot et al., 2004; 2005; Tenenbaum et al., 2004) and synchronous music (Hayakawa et al., 2000; Karageorghis et al., 2009); researchers have shown that the application of music, whether in the background or as a rhythmic movement cue, enables participants to derive more enjoyment in an activity as opposed to doing it in silence.

The lack of a significant difference between asynchronous and synchronous music conditions for in-task affective valence would suggest that the pleasure elicited from music listening does not seem to be influenced as much by the rhythmic aspects as was previously thought (Karageorghis et al., 1999; Terry & Karageorghis, 2006); in their conceptual frameworks, Karageorghis and colleagues proposed that rhythm response was considered to be most important factor in determining the motivational qualities of music and its subsequent benefits. Granted, these frameworks were designed for the asynchronous application of music, and may be deemed inapplicable for music synchrony. Yet the same frameworks have been suggested to explain the psychological and psychophysical benefits associated with synchronous music (Karageorghis et al, 2009). It has been proposed that the harmonic and melodic factors are more likely to influence affective responses, while rhythmical elements affect bodily response (Lucaccini & Kreit, 1972), a position that is further corroborated by the current observation that the metronome condition, devoid of any musical qualities other than tempo, did not elicit any increase in pleasure for participants.

It has been proposed that the extrinsic factors of music such as cultural impact and extra-musical associations have as much an influence as intrinsic factors on affective responses (Sloboda & Juslin, 2001) and this has been supported empirically by Bishop et al. (2007). Nonetheless, given the music used in the present study comprised obscure compositions that participants had no prior exposure to, or prior knowledge of, the chances of these extrinsic elements affecting the current findings are minimal. Further, Bishop et al.'s research dealt with music listening during the pre-event routines of young tennis players. The way music is being administered (i.e., pre-task or in-task) may thus dictate the influence of intrinsic and extrinsic musical factors on affective states.

The direction and magnitude of changes in arousal were similar to those reported for in-task affective valence. Surprisingly, only the synchronous music condition was significantly more arousing compared to the metronome and no-music control conditions. No differences were noticed for the asynchronous music condition in relation to the other conditions. This would imply that asynchronous music exposure did arouse participants, but not to the same degree as synchronous music; it would seem that the act of rhythm synchronisation interacted with musical qualities to elicit higher levels of arousal.

Alternatively, the lack of significance associated with asynchronous music might be down to a difference in tempo. The tempo of the music used in the asynchronous condition was 170 bpm, and this was 20 bpm higher than the music used in the synchronous condition. Through a series of exercise heart rate and music tempo preference studies (Karageorghis et al., 2006, 2008, 2011), it was proposed that to optimise the effects of music during exercise intensities of 60-80% maximum heart rate reserve (the current exercise intensity of 90% T_{vent} falls into this range), musical tempi should be between 135-140 bpm. Accordingly, the asynchronous music used in the present study was beyond this range, and might have been deemed to be overly stimulating, attenuating any possible increase in arousal due to music exposure.

This is, however, an unlikely scenario for two reasons. Firstly, the tempo of the synchronous music was 10 bpm above the upper limit, meaning that exposure to it should also have attenuated participants’ arousal levels, albeit to a lesser degree, according to the arousal-music tempo preference relationship (North & Hargreaves, 2008). This was clearly not the case as arousal under synchronous music was the highest among the conditions. Secondly, although the tempo of the asynchronous music and synchronous music were above the recommended tempo range by 30 bpm and 10 bpm respectively, both were deemed to be equally pleasurable by participants. This parity in affective valence measures might indicate that preference for both tempi was similar. Given the relationship between arousal and music tempo preference, it is unlikely that the difference in music tempi was the reason for the lack of significant increases in participants’ arousal levels under asynchronous music. Ideally, to truly isolate the effects of rhythm or tempo from other musical factors such as melody and harmony, the asynchronous music condition should be of a similar tempo to the synchronous music condition. Nonetheless, given the human predisposition to synchronise to musical rhythm (Wilson & Davey, 2002), it might be difficult to prevent individuals from subconsciously matching their movements to the tempo while listening to asynchronous music.

5.4.4 Limitations

There are several limitations that may have affected the findings of the current study. Firstly, during the course of the experiment, a potential problem was uncovered; although participants were able to keep to the prescribed pedalling rate of 75 rpm (±2 rpm) throughout each condition, it was noticeable that cadence was being maintained far more consistently in the control and asynchronous music conditions when compared to the synchronous conditions. Thus an analysis was performed on the variability of cadence to determine if this was indeed the case. Results confirm that cadence was significantly more variable in both synchronous conditions when compared to control, while the variability was not significantly different ($p > .05$) in the asynchronous music condition compared to the other conditions. A possible explanation may lie in the type of information participants receive to maintain the prescribed cadence. In the no-music and asynchronous music conditions, participants were presented with a visual display of their pedalling frequency, whereas in the synchronous conditions they were provided with an auditory stimulus. Accordingly, it appears that visual feedback may be more effective than auditory feedback for cadence maintenance.

Extant literature, however, indicates that auditory information is the most effective sensory feedback for enhancing performance in timing and rhythmic patterning tasks (e.g., Doody, Bird, & Ross, 1985; Lai, Shea, Bruechert, & Little, 2002; Shea, Wulf, Park, & Gaunt, 2001; Smoll, 1975). This mismatch regarding feedback effectiveness could quite possibly be due to task demands. Previous research (e.g., Doody et al.; Lai et al.; Shea et al.) employed simple discrete tasks to be learnt, whereas the present study utilised a task that was continuous in nature, and arguably familiar to all participants. Recent work by Liu and Jensen (2009) on the effectiveness of auditory versus visual feedback on the learning of a continuous cycling task revealed some interesting observations. Specifically, they found that participants performed less favourably when given auditory feedback compared to visual feedback in the acquisition phase of the experiment. However, in the retention and particularly the transfer tests, superior performance was recorded under auditory feedback in comparison to visual feedback. The task in the present study can be regarded to be novel; although cycling is an activity most people are familiar with, the requirement to pedal in synchrony with an auditory stimulus is not. Moreover, having to maintain an imposed cadence potentially increases the task demands. If this is the case, the current observation regarding feedback effectiveness can be accounted for. Future researchers may therefore wish to standardise the type of information feedback that is employed. Nonetheless, from a research perspective this is a limitation that cannot be avoided, if the aim is to isolate the effects of auditory synchronisation. Additionally, even though the pedalling rate was more variable for the synchronous conditions, it was still within the cadence limits prescribed.

It has been established that every person has a preferred tempo for a given task, and that this tempo varies from individual to individual (Smoll & Shultz, 1982). Accordingly, the imposition of a fixed pedalling frequency meant that most participants were cycling at a cadence that was not necessarily their preferred rate. This could have possibly reduced their mechanical efficiency, as participants were forced to alter their usual cadence to the level prescribed for the experiment.

However, the decision to impose a singular cadence rate across participants was taken to maintain the internal validity of the study.

Given observations reported in previous research of a similar nature (e.g., Bacon et al., 2012), the assessment of $\dot{V}O_2$ was considered an important aspect of the present study. Results from the current experiment however, suggest that physiological factors other than $\dot{V}O_2$ are affected by auditory synchrony; changes in overall metabolic cost (i.e., heart rate) were not reflected in oxygen uptake. The examination of a wider range of physiological indices, for example, EMG and blood lactate concentration, might have shed some light on the observed changes in heart rate. As mentioned previously, decreased variability in EMG patterns have been widely reported when movement patterns are synchronised with a timing mechanism. Such changes in EMG profile have been linked to more efficient motor neuron recruitment, which may have been reflected in a decrease in heart rate, as was the case in the present study. Reductions in blood lactate levels have also been reported, although in that instance the music was applied asynchronously (e.g., Szmadra & Bacharach, 1998). Nonetheless, if there are changes in heart rate and EMG when synchronising to an auditory stimulus, there is a likelihood that blood lactate levels would differ as well.

It might be argued that the duration of the exercise protocol was too short; music listening over a longer period of time might have elicited greater changes in affective states and RPE responses. Indeed, typical task duration in studies that have reported positive findings on psychological and psychophysical factors was longer than 1 min. For the present study, time and logistic constraints meant that it was not feasible to extend the task duration. Moreover, current findings would suggest that well-selected music is capable of inducing changes in perception and affective outlook fairly rapidly. Nonetheless, it would be interesting to see if the influence of music magnifies the responses observed in the present study if applied over a longer duration.

Results from the present study are only applicable to recreationally active males aged 18-35 years and should not be extrapolated to the general population. The influence and magnitude of differences associated with music use would likely differ for elite athletes, as well as a clinical population. Gender differences might also exist; females have been found to fare better than males in music-related activities due to their natural predisposition for rhythm (e.g., Karageorghis et al., 2010). In addition, current findings specifically relate to cycling and it is unclear if similar benefits, in particular physiological effects, are derived in other repetitive exercise modalities such as running, swimming, and rowing. This is likely, given the greater degrees of freedom in the movements of these tasks.

5.4.5 Implications and Future Direction

Two major findings from the present study hold potential implications for future music-related studies. Firstly, current findings would suggest that the psychological and psychophysical effects of music differ in accordance with its application; even though both music conditions resulted in positive changes to subjective arousal and peripheral RPE, only the synchronous music condition engendered significant changes when compared to the no-music control. Moreover, this observation would imply that a separate conceptual framework is required, or at least refinements to the current frameworks (i.e., Karageorghis et al., 1999; Terry & Karageorghis, 2006) to more accurately explain the effects of music synchrony in sport and exercise contexts. Secondly, reductions in heart rate under the metronome condition point to the possibility that synchronising to an auditory stimulus can result in some form of physiological change, although not in terms of oxygen economy, as observed by Bacon et al. (2012). Accordingly, the optimisation criterion remains an intriguing notion and warrants further investigation. The assessment of other physiological indices such as EMG and blood lactate levels might shed some light into possible efficiency gains that were not reflected in $\dot{V}O_2$.

The present findings are potentially relevant to music use in sport and physical activities, and possibly in clinical contexts where exercise is prescribed to facilitate rehabilitation or enhance wellbeing. Cyclists, who may deem performance outcomes to be more important than the experience of positive affective valence, could incorporate auditory-motor synchronisation to a metronome in order to boost metabolic efficiency during training. The use of synchronous music could also be considered for long training sessions to combat boredom and sensations of fatigue; but only when training indoors due to safety concerns. In addition, although music use is prohibited in outdoor competition, cyclists competing in indoor events such as individual sprint trials could certainly make use of music to boost performance. Exercise instructors involved with movement-to-music classes such as aerobics and spin, who might be more concerned with exercise adherence, should consider the use of synchronous music over asynchronous music; auditory-motor synchronisation appears to reduce perceptions of fatigue and increase arousal more readily compared to just listening to music in the background. At present, such classes merely give the impression music is used in a synchronous manner, when in reality the music is applied asynchronously. Exercise practitioners may wish to re-evaluate their position, considering the benefits associated with synchronous music use have been observed in the present study to be superior to those of asynchronous music. The same principles are also applicable to recreational exercisers, in particular those who partake in circuit-type exercise training (cf. Karageorghis et al., 2010) or endurance-based tasks (cf. Karageorghis et al., 2009). Another sub-population that could benefit from the present findings are patients prescribed bicycling exercises as a form of physical rehabilitation, although the use of a metronome might be more suitable for patients diagnosed with cardiac problems as it could possibly reduce the strain of exercise on the heart.

Even though participants exposed to asynchronous music were not significantly aroused or perceived any less peripheral fatigue when compared to the no-music control condition, the likelihood remains that the effects of asynchronous music might become stronger as the duration of an activity increases. Indeed, researchers that have reported reductions in perceived exertion used exercise protocols that lasted a minimum of 10 min (e.g., Nethery, 2002; Miller et al., 2010; Potteiger et al., 2000). Accordingly, exercise duration may be a mediating factor for the effects of asynchronous music on RPE. It would be worthwhile to investigate in future whether this is indeed the case. Moreover, exercise duration may also have an influence on the effects of auditory-synchronisation on metabolic efficiency; it is plausible any significant changes in oxygen economy may become detectable only after a certain period of time has elapsed.

Future researchers may also wish to investigate if the present findings are replicable across different sub-groups of the population. For example, elite athletes can be considered to have much narrower margins for efficiency gains in comparison to the untrained, given their superior physiological condition and expertise. Further, trained endurance athletes have been proposed to favour the use of associative strategies to cope with the demands of the task (e.g., Morgan & Pollock, 1977), although this proposition has been questioned recently; other studies have found conflicting results, indicating that one’s training status does not necessarily dictate the adoption of a particular attentional focus strategy. (see Lind, Welch, & Ekkekakis, 2009, for a review). The provision of an external stimulus such as synchronous music may therefore be an ineffective aid to such athletes. Another sub-group that should be examined in greater detail are females, who have been proposed to have an increased propensity and adaptability for movement-to-music related activities (Karageorghis et al., 2010). This proposition stems from the notion that women are generally exposed to dance and movement-to-music-type activities from an early age (see Shen et al., 2003), and accordingly, may be better at keeping in time than males. In addition, it would be interesting to examine whether similar findings are evident for different exercise modalities such as running, rowing, and swimming. This is a likely possibility, considering that such activities afford greater degrees of freedom in movement patterns compared to cycling, and would thus have more scope for kinematic improvements. Recent research by Terry et al. (2012) on the effects of synchronous music use during submaximal and exhaustive running does provide empirical support for this suggestion.

5.4.6 Conclusion

The present findings indicate that although auditory-motor synchronisation did not influence oxygen uptake, it did have an effect on heart rate. This could have implications for metabolic efficiency, though more research is required to ascertain if this is the case. The results also suggest that both synchronous and asynchronous music influence psychological and psychophysical responses differently, therefore there is a need for separate conceptual frameworks to detail the processes and responses associated with each application of music. The interplay between synchronisation and musical factors such as harmony and melody may have accounted for these differences. Participants cycling synchronously to music or to a metronome reported less perceived exertion compared to a no music control. In addition, music synchrony was the only experimental condition that significantly elevated arousal. These results were not observed when they cycled with asynchronous music, suggesting that (a) auditory-motor synchronisation affects RPE to a greater extent compared to the musical qualities and (b) auditory-motor synchronisation and the musical qualities interact in a manner that significantly increases participants' arousal levels. Several limitations were highlighted, the more important ones being the presentation of visual versus auditory feedback and the lack of other physiological measures such as EMG, though the former is a problem that cannot be easily circumvented in such studies.

Several recommendations were made for future researchers to consider in light of the current observations. Specifically, researchers should incorporate the examination of other physiological indices, in particular EMG, to determine the metabolic consequences of auditory synchrony. In addition, they may want to consider individualising cadence for each participant in order to fully maximise their cycling potential, although such a move might be a logistical challenge in terms of having to gather a large pool of music. Other recommendations include exploring gender and expert-novice differences, as well as extending the research to include other exercise modalities such as running, swimming, and rowing.

The present findings not only enhanced the current body of music-related research in sport and exercise, but also made several original contributions. Current observations suggest that synchronous and asynchronous music influence psychological and psychophysical responses differently, a finding that has not been reported in the literature. Further, the underlying mechanisms of synchronous music use have never been fully established; it is unclear how moving in time to a rhythmic musical stimulus engenders performance benefits. The present study indicates that auditory-motor synchronisation may be able to affect metabolic efficiency. This finding provides some support for the optimisation criterion as a valid concept to explain the ergogenic effects of music synchrony, although more research is required to test the validity of this concept. Future researchers seeking to investigate the different types of music application could use the observations reported in the current study to guide their research decisions. In addition, exercise and clinical practitioners can use the current findings to make more informed choices on music selection based on the type of activity, population, and desired outcomes.

Chapter 6: General Discussion

6.1 Introduction

The aims of this chapter are to: (a) review the main objectives and results of the research presented in this thesis with reference to extant theory and empirical findings; (b) discuss the implications of these findings for music-related research in sport and exercise; (c) highlight the limitations encountered through the course of the programme of research; and (d) present recommendations for practitioners and future researchers.

6.2 Review of Main Objectives

The main objective of the research programme was to investigate two areas underrepresented in the extant literature. Studies 1 and 2 were an extension of the present author's research on the effects of differentiated music exposure conducted prior to the current programme of research. The genesis for this idea stemmed from the fact that most music-related research has focused on the application of in-task asynchronous music in-task. In such cases, music was typically administered in its most basic form, without any manipulation of its intrinsic or extrinsic qualities (e.g., Atkinson et al., 2004; Boutcher & Trenske, 1990; Rendi et al., 2008). More recently, researchers have began to show more interest in manipulating properties of the musical stimulus; the effects of different musical qualities, tempi, and sound intensities have garnered the considerable attention from researchers in the past decade (e.g., Edworthy & Waring, 2006; Elliot et al., 2005; Karageorghis et al., 2009; Waterhouse et al., 2010). Nonetheless relatively little is known about the effects of manipulating musical stimuli in vivo, especially during long, repetitive events.

In recent times, researchers have called for the use of more externally-valid exercise protocols to investigate if laboratory findings are translatable to normal sporting contexts (e.g., Atkinson et al.; Karageorghis & Terry, 2009; Lim et al., 2009). Accordingly, a 10-km cycling time trial was selected on the basis that the task had ecological validity. In addition, a time trial facilitated direct comparison with previous studies of a similar nature (e.g., Atkinson et al.; Lim et al., 2009).

Chapter 5 focuses on another area of music-related research that has received relatively little scientific attention: The efficacy of auditory-motor synchronisation. Nonetheless, several studies have generally indicated that synchronising movement to an auditory stimulus such as music confers psychological, psychophysical, and ergogenic benefits (e.g., Anshel & Marisi, 1978; Karageorghis et al., 2009, 2010; Simpson & Karageorghis, 2006; Terry et al., 2012). However, not much is known about the underlying mechanisms that govern these outcomes. In addition, it is unclear whether the psychological and psychophysical effects of music differ when applied either synchronously or asynchronously. Only one set of researchers has directly investigated the two different applications of music in the same study, and their findings were inconclusive (i.e., Anshel & Marisi).

Cycling was chosen as a suitable exercise modality for this programme of research for two main reasons: Its familiarity to most people, and the high degree of standardisation and control that it affords in laboratory settings. The latter reason is important because it ensures that researchers can accurately assess the effects of music on physiological indices while maintaining high internal validity. This does not apply to activities such as running, swimming, and rowing, in which there is considerably greater scope for variations in technique among participants. Moreover, most people are familiar with the movement kinematics associated with cycling, and would therefore not require long periods of habituation.

6.2.1 Effects of Single-blinded Differentiated Music Exposure on a 10-km Cycling Time Trial

The first study in this programme of research follows on from previous work that investigated the effects of differentiated music exposure during a 10-km cycling time trial (i.e., Lim et al., 2009). Lim et al. raised several limitations in their study; namely, the need to establish internal validity, haphazard music selection, and the lack of a comparative condition that included music for the entire duration. This chapter therefore aimed to address these limitations, by employing a more appropriate and robust methodological approach. Findings established evidence for the efficacy of differentiated music exposure in self-paced protocols; participants, oblivious to the experimental conditions, reported positive outcomes for a variety of dependent measures: They were able to complete the 10-km time trials significantly faster when presented with music throughout (p = .01) and with musical accompaniment only for the last 5 km (p = .04), compared to a no-music control. A more in-depth analysis of the performance data indicates that increases in power output accounted for the shorter race times. More crucially, these increases occurred only during periods of music exposure, indicating that the presence of music elicited the changes in work output.

Participants were bearing a greater physiological load, without perceiving the elevation in workload; RPE was similar throughout (p = .11). These observations for RPE appear to contradict findings from the extant literature, which has shown music to be particularly effective at reducing perceptions of exertion, especially at low-to-moderate intensities of exercise (e.g., Boutcher & Trenske, 1990; Nethery, 2002). It was suggested that in self-paced protocols, music moderates RPE differently when compared to submaximal and exercise-to-exhaustion procotols (Lim et al., 2009). The absence of significant differences in RPE in this study does not imply that music was ineffective. In actuality, the presence of music during the time trials did have an influence on RPE ($\eta_p^2 = .08$), by suppressing perceptions of fatigue that would normally be associated with a higher workload.

The most interesting observation, however, was the impact of music differentiation on feelings of pleasure. A progressive decline in affective valence was reported by participants throughout the duration of the time trial, but this decline was absent in the condition in which music was presented in the second half ($p = .02$, $\eta_p^2 = .14$). Attentional models (i.e., Rejeski, 1985; Tenenbaum, 2001) were proposed as a possible explanation for the stability of affective valence observed in this condition. It was speculated that a switch in attentional focus, specifically from a predominantly internal to a brief external focus midway through the task, ameliorated the decline in affective valence that was associated with the demands of the task. Nonetheless, given the novelty of this observation, more research is required to deepen our understanding of this phenomenon.

6.2.2 Effects of Differentiated Music Exposure and Knowledge of Intervention on a 10-km Cycling Time Trial

Taking into consideration the findings of Study 1, in particular the impact of manipulated music exposure on affective valence, Study 2 was conceived in order to ascertain whether this unexpected finding is genuine. Further, given that music use, in reality, almost always entails a conscious decision, it was decided that participants would be informed of the experimental conditions prior to the start of each trial. As well as affording greater external validity, this approach provided an opportunity to investigate the possible influence of music on pacing strategies during cycling time trials. With this aim in mind, quantitative and qualitative analytical methods were employed to enable a more holistic understanding of the phenomenon under investigation.

The quantitative findings detailed in Study 2 appear to contradict those presented in Study 1: Although participants cycling in the experimental conditions completed the time trial faster than without music ($\eta_p^2 = .05$), these conditions did not differ significantly ($p = .33$). Significant changes were, however, observed for perceived exertion over the course of the time trial. Participants reported significantly less fatigue in the condition where music was presented in the second half when compared to music in the first half ($p = .02$) and a no-music control ($p = .04$). Although RPE was also lower when music was presented throughout the time trial, it was not significantly different from control. This indicates that music presented in the latter half was the most effective manipulation for distracting participants from the sensations of fatigue. Further, there were significant differences in affective valence; music in the second half of the time trial attenuated the rate of decline in affective valence far better than did music presented in the first half ($p = .004$) and the control condition ($p = .008$). In fact, this particular music condition appeared to be ineffective in eliciting any positive psychological and psychophysical responses.

Qualitative interviews with a subsample of participants yielded some interesting vignettes pertaining to their perceptions of the task and the experimental conditions that were administered to them. Participants generally felt that they did not formulate any particular pacing strategy prior to the commencement of each trial, although alterations were made in response to the music during the trials. Some participants asserted that listening to music for the entire duration of the time trial diluted the effects of musical accompaniment. It was proposed that in these instances, desensitisation had occurred, akin to Berlyne’s aesthetic theory of arousal potential (Berlyne, 1972). He proposed that the arousal potential of a piece of music is determined predominately by its collative properties, namely familiarity and complexity. This arousal potential follows an inverted U-shape relationship with music preference; moderately arousing music is most preferred, and preference tails off for music that possesses either low or high arousal potential. Accordingly, the prolonged exposure to music is likely to have reduced familiarity, thereby lowering its arousal potential.

Participants also indicated that the midpoint of the protocol was the most demanding segment, confirming the present author’s supposition that this may be an ideal point to introduce a pleasant auditory stimulus such as music. Moreover, among the experimental conditions, participants expressed the least preference for music presented in the first half of the time trial; these comments possibly indicate that participants attach greater significance to having music accompaniment in the second half rather than in the first half of the task. The presence of music in the first half of the time trial appeared to be inconsequential to participants. Other effects of music accompaniment that were mentioned by participants include the experience of flow, reduced perception of exertion, and attempted synchronisation, all outcomes that corroborate the extant literature on the benefits of music use in sport and exercise (e.g., Karageorghis et al., 2009; Nethery, 2002; Pates et al., 2003; Szabo et al., 1999)

6.2.3 Effects of Synchronous versus Asynchronous Music Application on a Short-duration Cycling Task

The final study in this programme of research attempted to address two shortcomings in the extant literature: The limited understanding of both the possible mechanisms that underpin the ergogenic effects of auditory-motor synchronisation, as well as the contrasting applications of synchronous versus asynchronous music. The basic premise of auditory-motor synchronisation is the matching of movement to a rhythmic stimulus. It was proposed that this synchronisation leads to more efficient movement kinematics, which underpins the purported performance effects associated with synchronous music application (Kenyon & Thaut, 2003). To this end, oxygen economy was measured as an indicator of efficiency and performance. In addition, a metronome condition was included to facilitate the assessment of the effects of rhythmic pacing and musical qualities separately.

Although there were no differences in oxygen economy across conditions (*p* = .52), a significant reduction in heart rate was recorded when participants cycled in time to the beats of a metronome in comparison to asynchronous music (*p* = .02) and a no music control (*p* = .05). However, a comparable effect was not observed in the synchronous music condition. A number of studies have shown that heart rate increases in response to stimulative/motivational music (e.g., Edworthy & Waring, 2006; Miller et al., 2010). These studies also found increased workload/endurance at a task. Accordingly, it is unclear whether the increases in heart rate were due solely to the music or the demands of the task, or a combination of both. Nonetheless, researchers in psychomusicology have demonstrated that listening to emotive music can elevate heart rate (e.g., Krumhansl, 1997; Rickard, 2004). Taking this into consideration, it was proposed that the musical qualities might have negated any possible reductions in heart rate associated with auditory-motor synchronisation.

In terms of perceptions of exertion, although central RPE was similar across all conditions, participants reported significantly lower peripheral RPE under auditory synchrony conditions (*p* = .01) compared to no-music control. This suggests that keeping in time with an external stimulus was a more potent distracter than listening to music per se. The nonsignificant influence of asynchronous music on peripheral RPE lies in contrast to extant literature, where it has been observed that the asynchronous application of during submaximal exercise reduces RPE when compared to no-music (e.g., Miller et al., 2010; Nethery, 2002; Potteiger et al., 2000; Szmedra & Bacharach, 1998). However, the protocols of the aforementioned studies entailed a minimum exercise duration of at least 10 min in duration, while the present task was only 6 min in length; the distractive effects of music listening may require more time to exert its influence. In the case of auditory-motor synchronisation, the additional demand of maintaining time (regardless of music) may take up more attentional resources compared to music listening, and thus have stronger distractive effects that can influence RPE more readily (cf. Johnson & Siegel, 1987). The results also suggest that there is an additive effect of auditory-motor synchrony and music listening (Karageorghis et al., 2009): Peripheral RPE was lowest in the synchronous music condition. attention away from internal physiological cues. Further, it appears that auditory-motor synchronisation is more effective on peripheral RPE than central RPE. Considering that the physiological demands were more taxing in the lower limbs as a function of the task, there is greater scope for peripheral RPE to be influenced by auditory-motor synchrony.

Affective states were also influenced by the presence of music, regardless of the mode of application. Participants reported more pleasure under the music conditions when compared to the metronome and control, although the combination of movement synchrony with the harmonic and melodic aspects of music elevated participants' subjective arousal levels significantly when compared to the metronome (p = .01) and control conditions (p = .03). These results were in the expected direction and in line with extant research that has consistently demonstrated that listening to music during a task elicits greater enjoyment (e.g., Boutcher & Trenske, 1990; Elliot et al., 2005; Hutchinson et al., 2010; Karageorghis et al., 2009; Tenenbaum et al., 2004).

It is evident that the effects of music differ according to its application; overall, results suggest that synchronous music is superior to asynchronous music, particularly in terms of reducing perceptions of fatigue as well as eliciting subjective arousal. In addition, even though $\dot{V}O_2$ was similar, the changes in heart rate while pedalling in synchrony with a metronome is an intriguing finding that warrants further investigation. An important point to note is that the duration of the task in the present study was relatively short (6 min). It is entirely plausible that changes in $\dot{V}O_2$ might have been observed over a longer exercise bout. Similarly, the effects of asynchronous music on RPE might be stronger in a longer duration task; existing findings certainly indicate this (e.g., Copeland & Franks, 1991; Nethery, 2002; Potteiger et al., 2000; Szmedra & Bacharach, 1998).

6.3 Emergent Themes

Collectively the three studies that comprise the present programme of research demonstrate the efficacy of music in eliciting a host of psychological, psychophysical, and ergogenic effects. Some of the current findings corroborate existing research (Atkinson et al., 2004; Boutcher & Trenske, 1990; Elliot et al., 2005; Karageorghis et al., 2009; Szabo et al., 1999), and provide further support for the use of music in sport and exercise. In addition, a number of novel findings emerged that complement the existing corpus of work and these are the focus of the subsequent sections.

6.3.1 Differentiated Music Exposure

The norm in research-related tasks as well as in the real world is to provide music accompaniment for the duration of an exercise task. However, it is evident from the findings presented in Studies 1 and 2 that introducing music at a pre-determined point can provide significant benefits, and in some instances, engender superior responses compared to the conventional application of music (i.e., listening to music for the entire duration). Moreover, the results from these studies indicate that a specific manner of music exposure (i.e., music presented in the second half) led to these responses; providing music only for the first segment of the cycling time trial had negligible effects on participants.

It is clear that listening to music for the entire duration or only for the latter stages of the time trial were more effective experimental conditions in comparison to music in the first half and a no-music control. The largest performance gains were observed when participants listened to music throughout the time trial, while the greatest reductions in perceived exertion and increases in feelings of pleasure were reported when music was presented only for the second half of the task. Further, findings in Study 2 were in a similar direction to those found in Study 1, although there were differences in the magnitude of effects. For example, in Study 1 the mean difference between race times for music in the second half and control was 27 s, while the mean difference for RPE and affective valence were .2 and .4 respectively.

However, in Study 2, mean difference between the same conditions were 15 s, .5, and .6 respectively. It is thus suggested that foreknowledge suppressed performance but enhanced the psychological and psychophysical effects of music. What is clear from the results of both Study 1 and Study 2 is that listening to music for the full duration of a task confers predominantly performance benefits. If the goal is to have a pleasant exercise or sporting experience, then listening to music in the second half of the activity might be deemed to be more appropriate.

A plausible explanation for the differences in psychological and psychophysical effects may be due to participants being desensitised to the musical stimulus; the prolonged exposure could have possibly reduced the music’s influence on RPE and affective valence. This view was reinforced by the qualitative findings presented in Chapter 4, wherein some participants spoke of the negative consequences regarding the constant exposure to music, particularly if the tracks were repetitive in nature. It is, however, noteworthy that even though participants’ RPE was higher and affective valence was lower in the condition with music throughout compared to music in the second half, race times were still the fastest in the former condition, in Studies 1 and 2.

Extant theory (e.g., Rejeski, 1985; Tenenbaum, 2001) and research have shown that music can positively influence RPE and affective states at low-to-moderate exercise intensities but is ineffectual at moderate-to-high intensities (Copeland & Franks, 1991; Nethery, 2002; Potteiger et al., 2000; Szmedra & Bacharach, 1998). Results from Studies 1 and 2, however, seem to indicate the opposite: The first half of the time trial can be considered to be less physiologically demanding compared to the second half, yet music accompaniment during the first part had a negligible influence on participants’ RPE and pleasure. However, both these measures were strongly influenced when participants were listening to music for the second half of the task, which is arguably more demanding due to fatigue accumulated from the first half of the trial. For example, RPE scores for Study 2 for the second segment of the time trial show that the condition with music only in the second half elicited approximately 6% reduction compared to the no-music control, and approximately 8% compared to the condition in which music was presented in the first half. The contradiction between current findings and those of past studies may possibly be explained by differences in task intensity; previous studies employed fixed intensity or exercise-to-exhaustion type tasks whereas a time trial is self-paced. Accordingly the effects of music may influence responses in a dissimilar manner when exercise intensity is self-regulated.

Researchers have observed that the moderating effect of exercise intensity on the influence of music applies only to RPE; music accompaniment has consistently been shown to improve affective states at high and even supramaximal intensities (e.g., Boutcher & Transke, 1990; Elliot et al., 2005; Hutchinson et al., 2011). Findings from Studies 1 and 2 lend support to this observation. Crucially, present observations indicate that the effects of music on affective valence were strictly due to the presentation of music in the second half of the time trial. Lack of motivation, accumulating fatigue, and increased perceptions of exertion are factors that can contribute to declines in affective valence (Backhouse et al., 2007; Baden et al., 2005; Frederick et al., 1996). These factors are more likely to manifest in the latter rather than the initial stages of the time trial. Accordingly, it is speculated that the influence of music on affective valence is minimal during the first half of the time trial because the effects of the aforementioned factors are negligible during these initial stages.

Critics might argue that because of the self-paced nature of the task, participants may have been working submaximally, but this is unlikely to be the case for two reasons. Firstly, mean heart rates in Studies 1 and 2 were in the range of 150-180 bpm. According to the Karvonen formula, an exercise intensity of 80% HRRmax, with age and resting heart rate fixed at 21years and 60 bpm respectively, corresponds to a heart rate of approximately 171 bpm. Therefore, participants in these Studies were likely to be working at a relatively high intensity. Second, Ekkekakis et al. (2010) observed that as exercisers crossed their T_{vent}, a sharp decline in affective valence ensued. Considering the valence profiles in both studies, it is speculated that participants were probably working at intensities around or above T_{vent}, which are considered to be relatively high (Ekkekakis et al., 2008; Goldberg, Elliot, & Kuehl, 1988), although it is quite possible for negative affect to be experienced during moderate-intensity exercise as well. Nonetheless, these two reasons collectively would indicate that the 10-km time trial was a physiological demanding task.

Lim et al. (2009) proposed that during the early stages of an event, energy levels would invariably be relatively high. Accordingly, during this initial period, exercisers would have no difficulty in maintaining high performance levels. However, as the task progresses, it is expected that such performance levels are unsustainable for the entire duration of the event, leading to a regulation in work output. This hypothesis has been supported empirically by investigations into the pacing strategy of cyclists: Initial stages are characterised by higher than average power output that subsequently declines and plateaus through to the latter half of the race, before an exponential rise towards the end (see St Clair Gibson et al., 2006). Therefore the provision of music at a point where fatigue is potentially high may serve to reverse the decline in power output by influencing perceptions of exertion and affective valence, leading to superior performances. This appeared to be the case in this instance, judging from the findings of Study 1 and Study 2.

6.3.2 Relationship between RPE and Pacing Strategy

The findings of Studies 1 and 2 appear to support and contradict what has been reported in the pacing strategy literature. Researchers have proposed that pacing strategies are an important component of a teleoanticipatory system (St Clair Gibson et al., 2005; Tucker & Noakes, 2011) that regulates performance to ensure that homeostatic processes are not severely disrupted. Elevated core body temperatures (> 40°C) have been shown to lead to the early cessation of a task (e.g, Nielsen, Hyldig, Bidstrup, González-Alonso, & Christoffersen, 2001; Nybo & Nielsen, 2001; Rasmussen, Stie, Nybo, & Nielsen, 2004). Nonetheless, during self-paced exercises wherein participants are able to freely manipulate their work output, it has been observed that workload is regulated before core body temperatures reach values that are considered dangerous (Tucker et al., 2004). These researchers also suggested that there is a reserve that enables additional output to be generated if required. In addition, it has been proposed that pacing strategies are dictated by a pre-determined RPE template: Work output is adjusted accordingly throughout a task to ensure that the template is maintained (Joseph et al., 2008; St Clair Gibson et al., 2005).

Present findings point to the existence of a teleoanticipatory system in the body that regulates work output according to the prevailing circumstances, such as the presence of music or the foreknowledge of music presentation (Noakes et al., 2005). It is speculated that the motivational and distractive qualities of music enabled the up-regulation of work output by tapping into the body’s reserve. Thus, current findings support the notion that psychological influences play as significant a role as physiological ones in the regulation of performance during self-paced exercise.

Contrastingly, researchers have proposed that pacing strategies are determined by a pre-programmed RPE template and work rate is regulated to maintain this template (St Clair Gibson et al., 2006). Findings from Study 2 clearly suggest otherwise: Although race times were not significantly different across conditions, participants reported significantly lower RPE when listening to music in the second half of the time trial compared to no-music. Moreover, RPE in the former condition was lower than the latter even during the first half of the time trial, in which there was no music for either condition. This possibly indicates some degree of pre-planning that not only took into account the influence of music per se, but also how it was presented. It appears that the notion of a rigid RPE template requires a rethink in light of the present findings reported in Study 2.

A key difference between Studies 1 and 2 was the prior knowledge of the experimental manipulation, and is likely the main reason for the differing results on race time and RPE. The positive correlations between workload and RPE are well established (Banister, 1979; Eston, Faulkner, St Clair Gibson, Noakes, & Parfitt, 2007; Hassmén, 1990; Löllgen, Ulmer, & Nieding, 1977; Noakes, Snow, & Febbraio, 2004). Nevertheless, it was suggested in this thesis that there is a relationship between music, performance, and RPE, especially in self-paced exercise protocols. Specifically, if music leads to an increase in performance without concomitant reductions in RPE, it does not necessarily imply that music was ineffective in lowering perceptions of exertion. Thus, the lack of an expected increase in perceived exertion due to greater workload would suggest that music had an influence on RPE. Conversely, when no performance gains are observed, one may expect participants to report less perceived exertion. This relationship is evident in extant research, but has never been conceptualised in such a manner (e.g., Elliot et al., 2005; Hutchinson et al., 2011; Nakamura et al., 2010; Nethery, 2002; Szmedra & Bacharach, 1998).

6.3.3 Synchronous versus Asynchronous Music

The findings of Study 3 highlight the potential differences between synchronous and asynchronous applications of music with reference to various psychological, psychophysical, and psychophysiological indices. The use of synchronous music significantly reduced perceived exertion ($p = .01$) and elevated subjective arousal ($p = .03$) when compared to control. This is not a novel finding, and is in agreement with the literature (e.g., Hayakawa et al., 2000; Karageorghis et al., 2009; Terry et al., 2012).

What is interesting, however, is that even though results were in a similar direction for asynchronous music, they did not differ significantly from control. This would indicate that synchronous music is a much more effective dissociative ($d = .6$ vs. $d = .3$) and arousing ($d = .7$ vs $d = .5$) aid. Surprisingly, no psychophysiological differences were noted between the music conditions and control, which was in contrast to recent research (e.g., Bacon et al., 2012; Terry et al., 2012). Nonetheless heart rate under the metronome condition was significantly lower in comparison to control, indicating the possibility that the act of auditory-motor synchronisation could confer some physiological benefit. More research, however, is required in order to uncover why the reduction in heart rate was not reflected in oxygen economy, and why reductions in heart rate were only observed in the metronome condition but not in the synchronous music condition. The possibility that the duration of the task was of insufficient duration to elicit stronger changes should not be ruled out; most studies that have reported significant differences were of at least 10 min duration (Bacon et al.; Terry et al.). On the basis of these results, it seems prudent to suggest that a separate conceptual framework is required that could accurately detail the effects associated with the synchronous application of music. Ideas such as the optimisation criterion (Kenyon & Thaut, 2003) and active attentional manipulation (Johnson & Siegel, 1987; Karageorghis et al., 2009) may be suitable building blocks on which to construct this framework.

6.4 Limitations

As with any programme of research, several limitations were identified. Some of these limitations could be rectified, while others are problems that are inherent to this type of research. Nonetheless, future researchers should take these limitations into consideration.

6.4.1 Individual Preference for Music

The appropriate selection of music has always been a contentious issue (Bishop et al., 2007; Karageorghis et al., 1999). Karageorghis et al. (1999, 2006) created the BMRI and its derivatives in order to provide a standardised method of music selection based on its motivational qualities. The use of this inventory has led to a significant increase in the quality of music related-research in sport and exercise (e.g., Crust & Clough, 2006; Elliot et al., 2005; Simpson & Karageorghis, 2006). Nonetheless, even though the music chosen for the first two studies in this thesis followed BMRI procedures, there were certain tracks that participants in the main experiments expressed a severe dislike for, and this may have influence their psychological and psychophysical responses. This is not a surprising finding, given that music preference is highly subjective (Bishop et al.; North et al., 2004). A possible solution to this issue of subjectivity is to obtain a large and constantly evolving database of BMRI-selected music which participants can choose from for use in the experimental phase. This would ensure a level of consistency with regards to the qualities of music yet, at the same time, afford some degree of flexibility to accommodate individual preferences.

Another proposition may be to use music that has been especially composed for use in sport and exercise, such as that employed in Study 3. In this instance, extrinsic properties of the music had little influence on participants given that they had never heard it before; music preferences were based predominantly on the intrinsic properties of the music (North & Hargreaves, 2008; Sloboda & Juslin, 2001). Although it is possible that participants' preferences would still be influenced differently by how they perceive the intrinsic properties of the music, the scope for subjectivity is greatly reduced by removing sociocultural and associative conditioning influences.

6.4.2 Motivational Quotient

The motivational qualities of music tracks chosen for use in both Studies 1 and 2 were between 22.8 and 29.6. These scores are only considered to be moderately motivating according to the BMRI-2 (Karageorghis et al., 2006). There is a likelihood that music possessing higher motivational qualities might have engendered more positive responses from participants. Further, qualitative reports from participants appear to indicate a preference for music of a faster tempo than that used in these two studies. Thus, the selection of music above 140 bpm should be considered for future studies, particularly if it involves completion of time trials. Participants' preference for music of high tempo may be related to North & Hargreaves' (2000) arousal-based goals; highly arousing situations leads to the selection of music with similar arousing standards in order to facilitate goal achievement.

6.4.3 Generalisability of Results

Participants who were recruited for the present programme of research, in particular for Studies 1 and 2, were 18-25 years of age and recreationally active. This particular demographic was chosen for two reasons: (a) compatibility with the sample involved in the music selection process and (b) their accessibility. Accordingly, caution should be taken in generalising the present findings to other sub-groups. Females, for example have been proposed to be more readily affected by music due to their exposure to dance and movement-to-music from an early age (Shen et al., 2003). Moreover, females have generally been found to have more positive attitudes towards music in comparison to males (North & Hargeaves, 2008).

Another sub-group that might yield different results are elite athletes. Studies have observed that high-level runners are more likely to adopt an associative rather than a dissociative strategy (Masters & Olges, 1998; Morgan & Pollock, 1977). Thus, there is a likelihood that elite athletes would not derive as much distractive benefits from music listening, which is often employed as a dissociative strategy Additionally, it is unclear if such gains as reported in Studies 1 and 2 are translatable to submaximal intensity exercise tasks of a fixed duration, but the findings of Study 3 would, to a certain extent, suggest that this is likely to be the case.

6.5 Future Directions

6.5.1 Segmented Exposure

Findings from Studies 1 and 2 indicate that the differentiated exposure of music during a task holds significant potential for future research, particularly in terms of moderating perceptions of exertion and pleasure. At present, the underlying mechanisms for the increased effectiveness of music presented in the latter stages are unclear. It is speculated that the introduction of a pleasant stimulus at a stage where fatigue is considerable can more readily influence perceived exertion and affective valence. The same effects are not observed when listening to music throughout, which may be a consequence of desensitation (e.g., Berlyne, 1974), wherein the effectiveness of music diminishes after prolonged exposure. Further investigation is warranted, and a possible future consideration could examine the impact of having an experimental condition with music presented periodically, and more importantly, at critical points during the task.

6.5.2 Synchronous Music

There is still a paucity of research into the use of synchronous music in sport and exercise, even though interest in this area has been gathering in recent years (e.g., Bacon et al., 2012; Karageorghis et al., 2009, 2010; Simpson & Karageorghis, 2006; Terry et al., 2012). The mechanisms that underlie the effects of synchronising movement to music are presently unclear. There is a considerable amount of neurophysiological research (e.g., Molinari, Leggio, de Martin, Cerasa, & Thaut, 2006; Thaut et al., 2009) mapping the neural structures involved in auditory-motor synchronisation, but it is still unknown how this is translated into superior motor performance. In Study 3 it was proposed that the concept of auditory-motor synchronisation is based on more efficient movement kinematics that may lead to better oxygen economy. Nonetheless, the findings failed to support this proposition. It was suggested by the present author that the duration of the task may have been too short and thus insufficient for auditory-motor synchronisation to exert its influence on VO2. Moreover, the assessment of other physiological indices such as

EMG and blood lactate concentrations might provide a more complete picture of the relationship between auditory-motor synchrony and its ergogenic effects.

6.6 Implications for Sport and Exercise

The current findings have many implications for sport, exercise, and potentially rehabilitation. First and foremost, there is now scientific evidence highlighting differences in the effects of music when applied synchronously or asynchronously; perceived exertion and subjective arousal are more positively influenced by synchronous music than asynchronous music. Given that synchronous music appears to generate more superior outcomes compared to asynchronous music, it could be suggested that the synchronous application should be implemented whenever possible. Nonetheless, more research is required to ascertain if this is indeed the case.

Depending on the outcomes desired, athletes could endeavour to use music during training sessions to boost the quality of their workout. If the goal is to maximise performance, listening to music throughout the entire duration may be more appropriate as it can enable athletes to achieve greater work outputs (Crust & Clough, 2006; Elliot et al., 2005; Hutchinson et al., 2011). Athletes may also choose to employ music only in the latter stages of a training session to ameliorate the negative feelings associated with fatigue. This can make training seem less tedious and more pleasurable, potentially leading to increased training volume. Moreover, auditory-motor synchronisation could improve performance outcomes, possibly by engendering more efficient movement kinematics (Kenyon & Thaut, 2003; Roerdink, 2008).

Similar principles apply to recreational exercisers, and particularly to exercise practitioners. In the physical activity, health, and exercise context, getting people to partake in exercise or physical activity, and committing to it in the long term has been a perennial problem (Ekkekakis et al., 2011, Lind et al., 2009). The considered application of music could thus be viewed as an inexpensive yet effective tool for encouraging people to take part in exercise (Karageorghis et al., 2009). In this context, the use of segmented music exposure may be a more appropriate application as it has significantly more positive influences on both perceived exertion and pleasure, factors which have been found to be strongly related to exercise adherence (Ekkekakis et al.) These recommendations are equally applicable to patients that have been prescribed exercise as a form of intervention (e.g., Baudolff et al., 2002; De Bourdeaudhuji et al., 2002; Murrock, 2002).

6.7 Conclusions

The present programme of research was developed to investigate two areas within music-related research in sport and exercise that have received scant attention: The differentiation of music exposure and the differences between synchronous and asynchronous music application. Collectively, the findings from all three studies indicate that participants listening to music achieved greater work output, perceived less exertion, and felt more pleasure; these outcomes corroborate the extant literature (e.g., Atkinson et al., 2004; Elliot et al., 2005; Karageorghis et al., 2009). In addition, findings from Studies 1 and 2 provide confirmation that the effects of asynchronous music are not confined to fixed intensity and exercise-to-exhaustion type tasks, and are also applicable to self-paced protocols. The main contributions of this thesis to the extant literature, however, are centred on the novel effects observed under differentiated music exposure, and the contrasting findings between synchronous music versus asynchronous music application.

Following on from previous work (i.e., Atkinson et al., 2004; Lim et al., 2009; Szabo et al., 1999), Studies 1 and 2 established that the listening of music only in the second half of a 10-km time trial attenuated task-related declines in pleasure and reduced perceptions of exertion; such effects were not noticed for the other music conditions. These findings would therefore suggest that the sudden introduction of music in the latter stages is the crucial factor; the presentation of music throughout a task did not exert similar influences on RPE and affective valence in the second half of the time trial. It is speculated that listening to music in the second half is more effective because of the increasing task demands as the trial progressed, but a prolonged exposure (i.e., music throughout) might have blunted the effects of music in the latter part of the time trial (cf. Berlyne 1974; North & Hargreaves, 2008). These are highly intriguing findings, and warrant further examination given the lack of research into this area.

Results from Study 3 provide clear evidence that the effects of music differ depending on its application. Participants in the synchronous music condition perceived less exertion and higher levels of subjective arousal in comparison to a no-music control. Although the effects engendered in the asynchronous condition were displayed a similar trend, the magnitude of effects was not significant. Taken together, these findings indicate that the synchronous music is a more effective application when compared to asynchronous music. A separate conceptual framework is thus necessary to explain the effects associated with synchronous music. The hypothesised notion of efficient movement kinematics was not supported by the current results on oxygen uptake, but this may have been due to the short exercise duration; researchers that have observed significant positive physiological responses with movement-to-music synchronisation typically employed tasks that were longer in duration (e.g., Bacon et al., 2012; Simpson & Karageorghis, 2004; Terry et al., 2012). It is maintained that the refinement of movement kinematics (i.e., optimisation criterion) remains a viable and theoretically sound concept that could account for the ergogenic effects associated with synchronous music use.

Collectively, the findings reported in the present programme of research demonstrate the efficacy of music use in sport and exercise. More importantly, these findings also challenge the traditional understanding of how music is applied, in particular the idea that music exposure has a positive linear relationship with the effects it engenders. The current results also provide clear indication that music elicits differing effects in accord with whether it is used synchronously or asynchronously. These findings have important implications for music prescription in both sport and exercise contexts, particularly if the aim is to induce greater pleasure. Non-compliance with an exercise programme is thought to be a major contributing factor to the physical inactivity epidemic (Lind et al., 2009). A possible reason for non-compliance relates to the link between exercise intensity and affective valence (Ekkekakis et al., 2008, 2011). In essence, high workloads lead exercisers to perceive the exercise experience as not enjoyable or intolerable, and subsequently are less likely to take part in the activity again (Lind et al.). In this regard, listening to music at an appropriate point during an exercise session may serve to make the experience more pleasurable, increasing the likelihood of repeated participation. Accordingly, carefully constructed music programmes could prove to be a highly effective yet inexpensive tool in the fight against the physical inactivity epidemic that is plaguing modern society.

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Appendix A

SCHOOL OF SPORT AND EDUCATION

FORM OF CONSENT TO PARTICIPATE IN A MAJOR RESEARCH PROJECT

Title of project:

I, ... (**Participant's** full name*) agree to take part in the above named project/procedure, the details of which have been fully explained to me and described in writing.

Signed .... Date ....

(Participant)

I, **HARRY LIM** (**Investigator's** full name*) certify that the details of this project/procedure have been fully explained and described in writing to the participant named above and have been understood by him/her.

Signed .... Date ....

(Investigator)

I, ... (**Witness** full name*) certify that the details of this project/procedure have been fully explained and described in writing to the participant named above and have been understood by him/her.

Signed... **Date** ....

(Witness)

NB... The witness must be an independent third party.

* Please print in block capitals

Appendix B

The purpose of this questionnaire is to assess the extent to which the piece of music you are about to hear would motivate you during exercise. For our purposes, the word ‘motivate’ means music that would make you want to exercise harder and/or longer. As you listen to the piece of music, indicate the extent of your agreement with the statements listed below by circling one of the numbers to the right of each statement. We would like you to provide an honest response to each statement. Give the response that best represents your opinion and avoid dwelling for too long on any single statement.

		Strongly disagree			**In-between**			**Strongly agree**
1	The rhythm of this music would motivate me during exercise	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2	The style of this music (i.e. rock, dance, jazz, hip-hop, etc.) would motivate me during exercise	**1**	**2**	**3**	**4**	**5**	**6**	**7**
3	The melody (tune) of this music would motivate me during exercise	**1**	**2**	**3**	**4**	**5**	**6**	**7**
4	The tempo (speed) of this music would motivate during exercise	**1**	**2**	**3**	**4**	**5**	**6**	**7**
5	The sound of the instruments used (i.e. guitar, synthesizer, saxophone, etc.) would motivate me during exercise	**1**	**2**	**3**	**4**	**5**	**6**	**7**
6	The beat of this music would motivate me during exercise	**1**	**2**	**3**	**4**	**5**	**6**	**7**

Appendix C

Individual track details of the music playlist for Study 1

Artist	Track	Time	bpm, BMRI-2 mean quotient
Cascada	Everytime We Touch	3:19	141, 22.875
Somebody told me	The Killers	3:34	137, 24.625
50 Cent ft. Justin Timberlake	AYO Technology	4:11	140, 26.375
T2 ft. Jodie Aysha	Heartbroken	5:28	140, 27
Smack my bitch up	The Prodigy	5:43	135, 28.75
Firestarter	The Prodigy	4:42	140, 29.5
Sandstorm	Da Rude	3:46	137, 29.625

Appendix D

HEALTH QUESTIONNAIRE

Name: ………………………………………….
Address: ………………………………………….
………………………………………….
Phone: ………………………………………….

Please answer the following questions. If you have any doubts or difficult with the questions, please ask the investigator for guidance. These questions are to determine whether the proposed exercise is appropriate for you. Your answers will be kept strictly confidential.

1	Are you male or female?		
2	What is your date of birth? Day………Month……Year…….. Your age is ………… years		
3	When did you last see your doctor? In the: Last week ……. Last month…….Last six months…… Year……. More than a year……		
4	Are you currently taking any medication?	Yes	No
5	Has a doctor ever advised you not to take vigorous exercise?	Yes	No
6	Has your doctor ever said you have ‘heart trouble’?	Yes	No
7	Has your doctor ever said you have high blood pressure?	Yes	No
8	Have you ever taken medication for blood pressure or your heart?	Yes	No
9	Do you feel pain in your chest when you undertake physical activity?	Yes	No
10	In the last month, have you had pains in your chest when not doing any physical activity?	Yes	No
11	Has your doctor (or anyone else) said that you have raised blood cholesterol?	Yes	No
12	Have you had a cold or feverish illness in the last month?	Yes	No
13	Do you ever lose balance because of dizziness, or do you ever lose consciousness?	Yes	No
14	Do you suffer from back pain? If so, does it ever prevent you from exercising?	Yes Yes	No No
15	Do you suffer from asthma?	Yes	No
16	Do you have any joint or bone problems that may be made worse by exercise?	Yes	No
17	Has your doctor ever said you have diabetes?	Yes	No
18	Have you ever had viral hepatitis?	Yes	No
19	Do you suffer from any hearing conditions, e.g. tinnitus?	Yes	No
20	Do you know of any reason, not mentioned above, why you should not exercise?	Yes	No
21	Are you accustomed to vigorous exercise (an hour or so a week)?	Yes	No

I have completed the questionnaire to the best of my knowledge and any questions I had, have been answered to my full satisfaction.

Signature: ……………………………………..

Appendix E

Individual track details of the music playlist for Study 2

Artist	Track	Time	bpm, BMRI-2 mean quotient
Cascada	Everytime We Touch	3:19	141, 22.875
Somebody told me	The Killers	3:34	137, 24.625
T2 ft. Jodie Aysha	Heartbroken	5:28	140, 27
Smack my bitch up	The Prodigy	5:43	135, 28.75
Firestarter	The Prodigy	4:42	140, 29.5
Sandstorm	Da Rude	3:46	137, 29.625

Appendix F

Interview Guide

1. How well do you think that you performed in each trial? (generic)
2. Did you have a strategy for completing each time trial? If so, what was it? (generic)
3. Can you recount any thoughts and/or feelings/emotions that you may have experienced during each time trial? (generic) Probe/elaborate – at which point precisely did you feel a particular way?
4. Did your perceptions of how hard the exercise felt change during the course of the time trial, for example were there any stages when it felt particularly easy or hard?
5. What are your views on doing the time trial with and without music, and the manner in which the music was presented? (specific)
6. What are your views on the musical selections that were played? (specific)
7. If you were able to choose your own music programme for static cycle exercise, what factors would you consider as being important and why? (specific)
8. What do you think the purpose of the experiment was? (specific)
9. What factors do you feel affected your performance today, and why? (specific)
10. Are there any other comments that you would like to add? (generic)

Appendix G

Research Output and Activity

Karageorghis, C. I., Jones, L., Priest, D. L., Akers, R. I., Clarke, A., Perry, J. M., … Lim, H. B. T. (2011). Revisiting the relationship between exercise heart rate and music tempo preference. *Research Quarterly for Exercise and Sport, 82,* 274-284.

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