UNIVERSITY OF SOUTHERN QUEENSLAND

EFFECTS OF SYNCHRONOUS MUSIC ON PSYCHOLOGICAL RESPONSES, PERFORMANCE INDICES AND PHYSIOLOGICAL FUNCTIONING AMONG ELITE TRIATHLETES AND RUNNERS

A Dissertation submitted by

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Abstract

To date, most studies looking at the effects of music in sport have focused on non-elite populations. The use of synchronous music has demonstrated ergogenic, psychological, and physiological benefits when used as an accompaniment to physical activity. The aim of the present research programme was to extend previous investigations of synchronous music to elite athletes. Study 1 assessed the benefits of synchronous music during submaximal and exhaustive treadmill running among elite triathletes. Time-to-exhaustion, mood responses, feeling states, ratings of perceived exertion (RPE), blood lactate concentration, oxygen consumption, and running economy were measured during three treadmill runs. Participants (n = 11) ran to motivational music using self-selected tracks, a neutral music condition, and a no-music condition. Time-to-exhaustion in the motivational and neutral music conditions increased by 18.1% and 19.7%, respectively, compared to the no-music condition. Other measures that indicated a benefit of music over no music included RPE (lowest in neutral music condition), blood lactate (lowest in motivational music) and oxygen consumption (lower by 1.0%-2.7%). In Study 2, the software necessary to conduct similar testing outdoors using Apple *i*Phones was developed. Six *i*Phones were programmed to gather GPS, cadence, RPE, Feeling Scale and BRUMS data, and were evaluated by two experienced runners. Study 3 investigated the benefits of music on training effectiveness. Participants were elite triathletes (n = 2) and elite runners (n = 6) who used *i*Phones while running to a synchronous music condition, a music-led condition, and a no-music condition. Both music conditions were associated with greater distances covered, lower RPE, and more positive feelings and mood responses. Results suggest that the judicious use of music can potentially provide significant benefits to elite athletes during training activities.

Certification of Dissertation

I certify that the ideas, experimental work, results, analyses, software, and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

Alessandra Mecozzi Saha — Date

ENDORSEMENT

Prof. Peter C. Terry (Supervisor) — Date

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CHAPTER 1: INTRODUCTION TO THE RESEARCH PROGRAMME

1.1 Music use in sport and exercise

With the development of modern technology such as mp3 players, never before has music been so popular in sport and exercise contexts. Research in the area of music applications in sport and exercise settings dates back to the early 1900s but music has been applied as for physical and psychological enhancement much earlier than that. For example, in biblical times, it was claimed that the Hebrews blew trumpets in battle and were inspired to win the battle of Jericho. In general terms, it has long been known that music has potential benefits when applied in sport and exercise contexts (Ayres, 1911, Lucaccini & Kreit, 1972). More recently, research efforts have focused on identifying specific personal, musical and situational factors that influence the effects of music in physical activity domains (see Karageorghis & Priest, 2012).

Some of the key features of research efforts to date include comparing the benefits of using synchronous versus asynchronous music. Synchronous music is a term used to indicate music whose tempo matches the pace of the activity, whereas asynchronous music is essentially background music that is not deliberately matched to the tempo of the activity. It is has often been proposed that synchronous music offers more benefits to athletes and exercisers than asynchronous music (e.g., Terry & Karageorghis, 2006) although the veracity of this claim is uncertain. The present research, by examining the effects of synchronous music, contributes to the discourse in this area. Another research thrust has involved comparing the effects of motivational versus *oudeterous* (neutral) music. Generally, findings have supported the efficacy of motivational music over music with lesser motivational qualities, although there is some equivocality in the literature (see Terry & Karageorghis, 2011). By testing the effects of both motivational and neutral music, the present research will help to clarify the uncertainty related to this variable. These matters and other common trends in the salient literature are revisited in more detail in Chapter 2.

1.2 The research rationale and programme

The current research programme aimed to progress existing knowledge in the area of music and sport. Although the benefits of synchronous music in sport and exercise have been documented previously (e.g., Karageorghis et al., 2009; Simpson & Karageorghis, 2006) there have been no previous studies testing use of synchronous music with elite athletes. Given the demonstrated benefits of synchronous music among non-elite athlete populations, the current research built on these results by conducting three studies considering synchronicity and selection of motivational music in tailoring a music playlist for elite athletes running in indoor and outdoor settings. A key difference between elite and non-elite athletes is that the former are already performing at the highest standards of human capabilities, leaving very little room for improvement. Hence, in the world of elite sport, where medals are won and lost by hundredths or even thousandths of a second, it is much harder to achieve performance enhancements. For this reason, elite coaches and athletes tend to only take into consideration the findings of studies that have used elite athletes as participants. This is what makes the present project so valuable. Parry, Chinnasamy, Papadopolou, Noakes, and Micklewright, (2008) investigated changes in mood and perceived exertion of elite triathletes before and after an Ironman Competition and found that both were correlated to an athlete's performance, suggesting that using music to influence mood and RPE would be relevant to enhancing performance in such a population.

Indoor exercise, such as treadmill running, is part of regular training. Developing new software applications for use with smart phones will allow for more sophisticated data collection in naturalistic settings, especially training environments. After evaluating the benefits of music for elite athletes in a laboratory setting in Study 1, custom-designed software for the Apple *i*Phone was developed in Study 2 to deliver a new application capable of facilitating relevant data collection in field settings and for athletes to select and use music that matches the contextual and individual requirements. Although the technology will not allow for the same level of physiological monitoring that is possible in a laboratory (such as measures of blood lactate and oxygen consumption), the psychophysical and performance data that will be collected in a training/competition setting outdoors in Study 3 will provide valuable information for coaches and athletes.

The stimulatory benefits reported with music are conditioned through an association of affective responses, which are strengthened with reinforcement, or exposure. The synchronicity of the music with an activity, in particular, has been associated with significant benefits in performance by using the rhythm of a musical piece to coordinate movement and regulate pace of the activity. The current research will thus elaborate on the qualitative experience and quantitative effects that can enhance performance by using synchronised music during running performance with elite athletes in a laboratory task (Study 1), develop a new application using an *i*Phone 3G (Study 2) to gather field data from elite athletes during training runs (Study 3). The outcome of the current research programme will provide athletes, coaches and trainers with a tool to enhance ideal running performance targets, such as performance times and pace, in elite sport.

1.3 General programme overview

The first aim of the research programme was to extend upon the previous research that had been conducted using synchronous music to accompany exercise performance in indoor settings. The population targeted for this study was elite athletes, as no previous studies in this area include elite sport populations, possibly due to the difficulty in recruiting these participants. Once the benefits of music were documented indoors, the second objective was to engineer modern technology toward the development of a software programme capable of collecting as much relevant data during elite athletes' regular training sessions outdoors. The use of *i*Phones as a vehicle to deliver the music, and simultaneously support the software for data collection, was subjected to testing prior to use with elite athletes. Finally, the distribution of music intended to enhance psychophysical and physical performance and gather data using an *i*Phone for validating the use of synchronous music on elite athletes was tested in a field setting. In establishing these objectives, the overall goal for this project was to determine whether there was a meaningful margin of improvement that synchronous music would provide to elite athlete performance.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction to the review

The effects of music are an increasingly popular topic in sport and exercise psychology. The process by which the benefits of music in sport and exercise can be optimised has generated interest from researchers and exercisers alike (not to mention the music industry!). Although there is much evidence that demonstrates benefits of music in sport and exercise settings, some music research has shown no associated performance enhancement; in some cases music has been shown to be detrimental to performance, particularly with trained participants (Brownley, McMurray, & Hackney, 1995). This finding could be extended to infer that music would not be able to assist elite athletes. However, in televised sport, many elite athletes can be seen wearing headsets en route to an event. Furthermore, many elite athletes have expressed their preference for music before engaging in competition and during training, including Olympic champions Michael Phelps and Federica Pellegrini. Indeed, sprint champion Usain Bolt is in talks to design his own line of headphones specifically designed for exercise settings (http://espn.go.com/blog/playbook/sounds/post/_/id/1666/usain-bolt-designs-own-line-of-headphones). It is clear from anecdotal reports that music assists athletes in elite sport. The central question therefore is, not whether, but rather, *how* does music assist elite athletes?

The present review integrates the existing literature on the benefits of music, specifically in the sport and exercise domains. In doing so, it aims to identify the common patterns in use of music, as well as their indirect implications, to construct a valid basis for the current study. Swimmer Michael Phelps' stated preference for listening to rap artists Lil' Wayne and Eminem. Similarly, swimmer Federica Pellegrini, Italian Olympic medallist, listens to Katy Perry during competition and training. Listening to the track *Scatman* by Scatman John reportedly assisted Haile Gebrselassie in setting a world record in the 2,000 m in 1998 (Simpson & Karageorghis, 2006). Usain Bolt endorsed the Chris Martin (featuring D-Major and Agent Sasco) track *Real Friends* as the last track he listened to before his 19.19 secs 200 m world record in 2009. Much research has already been conducted to attempt to understand the process by which music can apparently enhance such physical performances.

2.2. Theoretical basis of the research programme

Karageorghis, Terry, and Lane (1999) developed the first theoretical framework to predict the benefits of music. This model incorporated the internal and external factors of music, such as rhythm (internal) and/or associations of a musical piece (external) contributing to its motivational properties. These factors were assigned hierarchical value based on salience toward motivation, with rhythm being the most salient. Increased motivation was proposed to subsequently lead to psychological and physical benefits (see Figure 2.1).

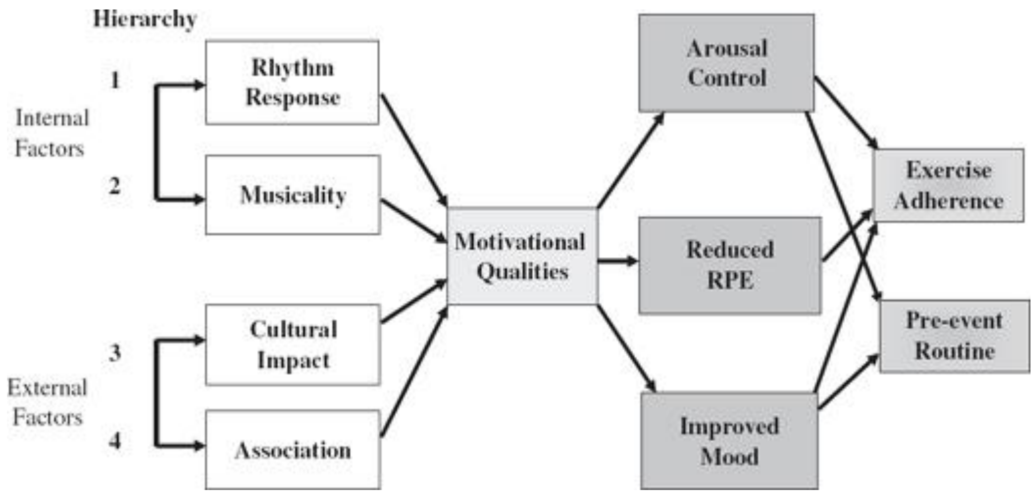

Figure 2.1. Conceptual framework for the prediction of responses to motivational asynchronous music in exercise and sport.

In 2006, Terry and Karageorghis proposed a new, somewhat simplified model specifically for sport and exercise applications, which is the model underpinning the current programme of research (see Figure 2.2). The four key factors contributing to the motivational qualities of music were retained, according to their salience: rhythm, musicality, cultural impact, and associations. The first factor, rhythm response refers to the natural tendency to respond to rhythmical aspect of music, especially tempo as measured in beats per minute (bpm). The second factor, musicality, relates primarily to the harmony and melody of a musical track. The first two qualities mentioned are regarded as internal motivators because the preference for these comes from within an individual. The third factor, cultural impact, takes into account the popularity of a track or musical genre enjoyed by a specific culture or part of society and, fourthly, associations attributed to a musical piece from prior exposure and associated experiences is also thought to influence the listener's experience of the music. An example might include Aerosmith's *Don't Wanna Miss A Thing* in the movie Armageddon, which may inspire the listener to recall the feeling of a dramatic turning point as a straw is drawn to determine which character (out of the three main protagonists) will die. According to this model, the benefits to be yielded by careful selection of music are improved mood, arousal control, dissociation, reduced RPE, greater work output, improved skill acquisition, flow states and general performance enhancement.

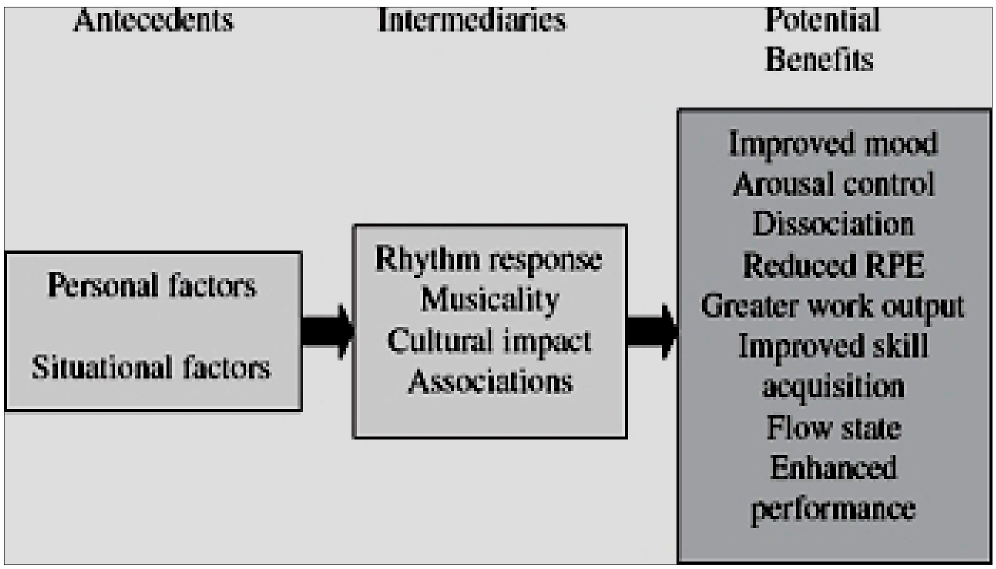

Figure 2.2. Conceptual framework for benefits of music in sport and exercise settings.

Cultural impact and associations are deemed to be external factors as they relate to the social musical experience. For example, an interesting study showed the influence of musical culture as a factor in the purchasing of wine. An experiment by North, Hargreaves, and McKendrick (1999) looked at the influence of different cultural music being played while wine was being purchased, which showed that consumers listening to French background music were more likely to select French wine while consumers listening to German music were more likely to purchase German wine. Cultural impact exists also within subgroups of a homogeneous society. In another example, a study by Geringer and Nelson (1979) looked at music during task performance in puzzles with individuals from the same society but with different musical backgrounds. Individuals with stronger musical exposure in their upbringing show a tendency to focus on music while performing another task. These individuals show a higher ability to parallel process information and show greater autonomy in musical selection in picking a motivational track.

Associations can be evoked with tracks that reference certain emotional states, such as the track, *Don't Worry, Be Happy*, by Bobby McFerrin. The lyrics encourage the listener to be happy by also suggesting that with any trouble, "when you worry you make it double" so "don't worry, be happy". A tool to evaluate a musical track in terms of its motivational properties was developed by Karageorghis et al. (1999) called the Brunel Music Rating Inventory, or BMRI, which is described later in the review.

2.3. Proposed mechanisms for the influence of music

Recent consideration of the underlying mechanisms involved in emotional responses to music was provided by Juslin and Västfjäll (2008), who combined the context and findings of previous musical studies into six proposed mechanisms. Their work has extended the notion that music induces emotion primarily via cognitive appraisal (Marin & Bhattacharya, 2009).

The first proposed mechanism, *episodic memory*, is similar to concept of association used in the theoretical model by Terry and Karageorghis (2006). Episodic memory explains music as a medium capable of generating an emotional response in relation to, or in association with, a particular experience or time. This mechanism can be related to any instance when musical song or track elicits a response associated with a particular memory.

Similarly, another proposed mechanism is referred to as *evaluative conditioning.* This mechanism illustrates how classic conditioning, such as repeated pairing of a musical piece with positive or negative stimuli, can cause a link so that the desired response is evoked each time that musical piece is heard. *Visual imagery* is also proposed to explain how music becomes associated with an emotionally-valenced image and creates an emotional response. Terry, Dinsdale, Karageorghis and Lane (2006) have demonstrated the effectiveness of imagery as a mood regulator; this proposed mechanism draws further appeal wherever lyrics assist the visual stimulation of an image.

Emotional contagion, the fifth proposed mechanism, supports the passing on of an emotion by transference of a song or musical track. In this mechanism, the brain is said to mimic the activity associated with the emotional content of a song or track. The neuroscientific data supporting this mechanism has shown that the brain will mimic the same emotional response as that found in the emotional content of the music (Koelsch, Fritz, von Cramon, Muller, & Friederici, 2006). The *brain stem reflex* is a process by which the brain responds to the acoustical properties of music, such as fast and loud music, signaling a potentially urgent event, consequently stimulating an emotional response from the central nervous system.

Finally, the sixth proposed mechanism would suggest that *musical expectancy* would play a role in extrapolating the overall effects of a song. For example, a song that is familiar or whose genre is familiar, will lead the listener to anticipate a pleasant experience and positive mood. For example, a song with enjoyable lyrics will lead the listener to look forward to the lyrics and thereby enhance affective responses. The aforementioned theories seek to illustrate how music can extract a reaction because being able to capture that mechanism means being able to recreate a desirable reaction and that can have extremely valuable applications.

In the exercise domain, the beneficial effects of music have been demonstrated to enhance running performance by increasing time-to-exhaustion (Karageorghis & Priest, 2012). In developing a theory as to how music can assist in such a task, Rejeski (1985) developed the parallel processing hypothesis. This hypothesis highlights the potential to relegate attention from internal stimuli to external stimuli through a change in attentional processing. The attentional capacity of an individual is thought to be more pliable at low-to-moderate intensity work-outs, reflected in lower rates of perceived exertion (Borg, 1982). Below the anaerobic threshold, an individual's attention has been hypothesised to shift more readily from internal physiological cues to external elements of music, particularly rhythm (Karageorghis & Terry, 1997). This would be beneficial in decreasing internal cues, such as fatigue, during repetitive movements that require little attention (Clynes & Walker, 1982). However, at work-out intensities above the anaerobic threshold, attention to external cues decreases (Boutcher & Trenske, 1990). Examples of demanding physical cues that dominate during high intensity work-outs mimic a state of survival mode. These cues, such as pulsating heart beats, heavier and/or faster breathing cycles, muscular pain and feelings of fatigue, take over the full capacity of signals that the afferent nervous system pathway can send to the brain at any given time. Nethery (2002) supported the notion of competing stimuli and, thus, limited attentional capability. Recently, however, research findings have suggested that it is still possible to influence the experience of such survival responses even during high intensity work-outs (Karageorghis et al., 2009).

There is also scientific postulation about how psychobiological consideration may help explain how music improves motor coordination performance (Bernatsky, Bernatsky, Hesse, Staffen, & Ladurner, 2004). Researchers at the Stanford University School of Medicine have conducted fMRI scans to observe the areas of the brain that are active during music listening of short 18th century symphonies. Interestingly enough, music activated the part of the brain which is responsible for paying attention, prediction-making and updating working memory (Sridharan, Levitin, Chafe, Berger, & Menon, 2007). It was also found that transitional points in musical pieces were pivotal in helping the brain organise information. The transitional moment between a symphony’s many movements re-captures any wandering attention and re-synchronises the brain’s response to the music. Each time this happens, information is stored and can be referred to as an event. Before new information can be stored, the brain updates the latest event into its working memory. Many transitions create a series of events that, together, form a continuous flow of information. The brain makes sense of these events by a process called “event segmentation”. During event segmentation, the brain organises information and uses this information to make predictions regarding future events.

Music has been used as a tool to study these transitions and decipher the brain's activity during the segmentation process. In a study with 10 men and 8 women, eight symphonies by William Boyce (1711-79) were chosen for their familiar style, less recognised composer and well-defined transitions. Given that the participants were musically untrained, the transitions were defined by a brief state of silence that even an untrained ear could recognise. The music was played within an MRI capsule, in which participants were instructed to simply listen to the music. Between movements, researchers found that the transitions ending the first movement excited activity in the ventral fronto-temporal area. The beginning of a new movement, or event, then excited activity in the dorsal fronto-parietal area, which stimulated updates in the working memory. Thus, music was hypothesised to be a helpful tool in improving the brain's ability to organise information quickly. The nature of music acts like a practice ground for the brain to exercise its attention skills and track information to anticipate future events. Systematic rhythm facilitates anticipation that a new event is about to occur. Tracks with less systematic rhythm will evoke different segments rather than a continuous sequence. This occurs when an incorrect anticipation activates a similar ventral area of the brain during that segment. The brain is juxtaposed to tangent this event off the sequence into a separate segment. This mechanism may explain how we are able to follow one conversation in a crowded room of many conversations (Sridharan et al., 2007).

The synchronous properties of music have been implicated as an important factor to consider when selecting music that is capable of providing benefits to the listener (Terry & Karageorghis, 2006). When music was used synchronously in a training programme by Kodzhaspirov, Zaitsev, and Kosarev (1986), results showed that participant mood was improved and, in most cases, music was deemed to be motivational. Older studies, including that by Smoll and Schultz (1978) looked at relationships between rhythm and motor execution involving 200 participants, half male, half female. Preferred tempo was selected in concordance to an arm-swing with results indicating that self-selected tempo was a significant predictor of motor skill performance. Preferred asynchronous music (i.e., self-selected music that did not match the pace of the activity) was not effective in enhancing performance though it may provide a distraction during continuous endurance tasks (Karageorghis & Terry, 1997). Smoll and Schultz (1982) later looked at rhythmic performance as a function of tempo by allowing participants to conduct an arm swing with three different tempi, one of which was deemed to be preferred by the participant. The findings showed that performance was maximised when the music tempo matched the activity and was also preferred by the participant. When considering the use of music to accompany an activity, the synchronicity of the music to the activity and the individual's preference for a certain song are two key elements that will maximise the benefits of the selected music.

Clynes and Walker (1982) referred to the ability of the central nervous system to execute repetitive movements, such as running, without continuous attention as *time form printing.* This concept suggests that only the initial movement requires full attention. Using running as an example, attention would be required to start the run and coordinate the movements initially. However, once a regular pace had been established, most attention could then be redirected elsewhere. Thaut, Kenyon, Schauer, and

McIntosh (1999) suggested that there may be an interaction between auditory rhythm and physical response. Thaut et al.’s (1999) findings preceded a study by Schauer and Mauritz (2003) with relevant findings to competitive sport settings today. That is, Schauer and Mauritz (2003) found benefits with musical walking performance on hemiparetic patients, suggesting that a fixed memory in the patient's mind with regular timing could even stimulate the improvement of gait without an external pacemaker. The reason why this is an incredibly meaningful result to competitive settings is that the benefits retrieved from musical memory would be particularly since the banning of music in such settings, such as that enforced by New York marathon organisers in 2007 (Karageorghis & Terry, 2009).

Synchronous music may also increase metabolic efficiency by promoting a more regular movement pattern (Smoll & Schultz, 1982). Recent fMRI studies have indicated the possibility of tuning into a preferred beat after the ventral premotor cortex, the area of the brain contributing to movement and integrating input, showed activation with preferred tempo (Kornysheva, von Cramon, Jacobsen, & Schubotz, 2010). Previous research has also confirmed that an individual’s background can affect their reactivity to music. Though not as salient as rhythm, the Terry and Karageorghis (2006) conceptual model suggests that factors relating to personal and situational contexts are still considered relevant in selecting the appropriate music for producing benefits on performance. Age, gender, familiarity and preference have all been studied in the context of influencing music reactivity in sport and exercise contexts (Crust, 2004; Dyrlund & Wininger, 2008; Priest, Karageorghis, & Sharp, 2004). Age was shown to be a more influential factor in musical reactivity than gender (Priest et al., 2004), whereby older adults demonstrated a motivational preference for slower music. In a study using familiar music vs. unfamiliar music (Crust, 2004), results showed that both music conditions yielded greater distances in treadmill walking performances, with participants stating a greater preference for a familiar musical accompaniment. These results are consistent with the notion that careful selection of music used during performance is relevant to performance enhancement outcomes.

2.4 Effects of music on psychological functioning

Konečni (1982) predicted that the difference in aesthetic preference for music is a function of past experiences associated with that musical selection, as well as the present psychological state and the resulting affective responses. Properties of a musical piece that determine whether a track is motivational include rhythm, harmony, melody, tempo and dynamics. In assembling selective factors that contribute to musical preference, Berlyne (1974) suggested that individuals prefer music that is moderately stimulating, such as would be indicated by moderate ratings of arousal, as opposed to music that is too little or overly stimulating. The latter notion is supported by more recent theoretical developments (Juslin & Västfjäll, 2008) and research findings (Karageorghis et al., 2011).

A grounded theory approach undertaken by Bishop, Karageorghis and Loizou (2007) with tennis players, using music to manipulate emotional states showed that participants purposefully selected music with the following goals in mind: improved mood, increased arousal and to elicit and/or accompany visual and auditory imagery. The properties of a track that made participants more likely to select it for a particular purpose included extra-musical associations, inspirational lyrics and enjoyable musical properties, all corresponding to the desired emotional state.

Volume also plays a factor in determining musical preference. Since music can potentially cause a temporary hearing loss when coupled with exercise at volumes greater than 79 decibels (dB), 79 dB is the recommended maximum volume (North & Hargreaves, 1995). Edworthy and Waring (2006) tested the effect of volume on exercise performance. Music selections consisted of two jazz pieces by the same artist, one fast (200 bpm), and one slow (70 bpm), which were unfamiliar to participants and were each played through headphones at two levels of loudness (60 dB and 80 dB). In line with previous findings, participants enjoyed what they were doing more when they were listening to music of any sort compared to when they were not. There was also a trend towards reporting fast music in a more positive light than slow music. Interestingly, the effect of volume was found to be dependent on the tempo of the music. There was a large effect of volume in the fast music conditions, but for the slow music conditions the effects of volume were not significant.

Louder sounds appear to affect movement by producing faster reaction times (Burt, Bartolome, Burdette, & Comstock, 1995; Haas & Casali, 1995; Haas & Edworthy, 1996) and increasing arousal (Jones and Broadbent, 1987). Heart rate increased if the volume of fast music increased, but not if the volume of slow music increased. Therefore, the added benefits of playing music loudly were only present when the music was fast. In terms of aesthetics alone, the loud/fast and the quiet/slow versions of the stimuli were shown to be the most aesthetically pleasing, thereby creating the most enjoyable experience (Edworthy & Waring, 2006). A study by Doiron, Lehnhard, Butterfield, and Whitesides (1999) played loud fast music (70-80 dB; 120 bpm) and found no changes in the number of repetitions performed during an exercise circuit trials, however, it is worth noting that the high intensity at which the repetitions were performed likely nullified any possible benefits of the music.

In 1993, Gluch used a qualitative approach to assess whether music influenced affect prior to competition. Gluch claimed that music was likely to work as a stimulative cue to cognitive thought processes and mental preparation strategies prior to performance, and as a performance-enhancement tool when used to create music highlight videos of optimal performance to increase confidence. However, the qualitative nature of the study makes these claims subject to critical scrutiny and point to a need for replication.

With respect to mood responses, Terry et al. (2006) showed that music is perceived to be one of the most popular and effective ways to boost athletes' mood prior to competition and Thayer, Newman, and McCain (1994) have shown similar mood benefits of music in the general population. Brownley et al. (1995) showed benefits of music on mood states using sedative music, whereas Terry and Karageorghis (2006), Elliott, Carr, and Savage (2004), and Edworthy and Waring (2006) have demonstrated the advantage of stimulative music for mood enhancement.

Positive emotions and outcomes result in motivation to repeat the behaviour that elicited a positive psychological state (Godin, 1994) which is why measuring feelings and perceived exertion during and after exercise are appropriate measures for individuals looking to identify, sustain and improve participation at any level of activity.

A study conducted on test anxiety, for example, showed that stimulative music increases anxiety, decreases concentration and lowers successful expectations (Smith & Morris, 1977) but later the opposite was found to be true in a similar study conducted by Blanchard (1979).

Motivation can be enhanced using music that has a direct link to sport and physical activity (Karageorghis & Terry, 1997) as well as music that does not have direct links to sport or exercise, provided that it promotes the desire to participate in the activity, for example, through its lyrics (Priest et al., 2004). Boutcher and Trenske (1990) compared mood states during low, moderate and high intensity workloads and found that elements of mood were affected at high work intensities (i.e., fatigue, anger, depression) when the music used was considered upbeat and stimulative. Lee (1989) examined the effects of baroque music and rock music in comparison to no music and results indicated that rock music, considered as stimulative, had an uplifting effect on mood after a submaximal treadmill running exercise. Macone, Baldari, Zelli and Guidetti (2006) showed that music enhanced the exercise experience and allowed participants to push themselves into a harder and more rewarding workout session in treadmill running performance. Overall, there is relatively consistent evidence of the potential benefits of music on psychological responses, including in-task feelings and post-task mood.

2.5 Effects of music on psychophysical functioning

According to the Terry and Karageorghis (2006) model, a reduction in ratings of perceived exertion is a benefit that can be obtained when the appropriate music is selected to accompany exercise. Developing an individual's physical potential is one of the benefits of lowering RPE during work output. Producing more work for the same effort, consistently, will raise the threshold of what then becomes the new standard of operating and performing in training and competition for athletes, which could result in an elevated seeding or elite status.

The benefits of music on RPE can also lead to positive changes to exercise adherence (Miller, Swank, Manire, Robertson, & Wheeler, 2010) but identifying the effects of music on psychophysical measures, such as RPE, has proven to be challenging for researchers. Studies that have looked at RPE have typically used asynchronous music. Boutcher and Tresnke (1990) found that effects of asynchronous music on RPE were influenced by the intensity of the work being completed, supporting a load-dependent theory (Rejeski, 1985). A study by Copeland and Franks (1991) showed that RPE could be significantly lowered when soothing music was played during moderate work; significant benefits of music on RPE and emotion were later confirmed by Seath and Throw (1995). A more recent study by Kreitinger (2010) showed that RPE was reduced using music during running performance. An increased running speed was demonstrated with the use of music whose tempo was greater than 130 bpm with no concomitant increase in RPE, even though additional work was performed. However, Schwartz, Fernhall, and Plowman (1990), using stimulative music, found that music did not benefit RPE significantly in comparison to a no-music condition. In general, most studies have concluded that music has a positive effect on RPE during submaximal exercise, although its effects are inconsistent and unclear.

Although Mohammadzadeh, Tartibiyan and Ahmadi (2008) found that benefits of music applied to individuals across various levels of fitness, one factor that has stood out amongst the research is that participants who derived benefits in RPE from the use of music were considered to be untrained, in terms of their fitness, and therefore the conclusion that music can reduce RPE in untrained individuals has required explanation. One theory postulates that untrained individuals tend to focus on external stimuli, whereas trained individuals tend to focus more on their inner cues. Szabo, Small, and Leigh (1999) found combined benefits when music was used during performance, including reduced fatigue, increased relaxation, improved motor coordination and increased levels of mental arousal. Of those four benefits, three (i.e., reduced fatigue, increased relaxation and increased mental arousal) are psychological. The mechanism by which music appears to decrease fatigue is by distracting an individual from unpleasant stimuli during moderate exercise. At higher intensity levels of exercise, music was not effective at distracting individuals from more powerful feelings of pain and fatigue because, at high exercise intensity, the vital cues the body emits demanded more urgent attention (Karageorghis & Terry, 1997).

In another test of psychophysical functioning, the benefits of music on rate of perceived exertion were examined in a study by Atkinson, Wilson and Eubank (2004). Participants pedalled 10 km under music and no-music conditions. Results showed that participants perceived less effort during the first 3 km in the music condition compared to the no-music condition; furthermore, participants completed the test faster in the music condition. Additionally, perceived exertion appears to be lower when participants exercise to music. Music, therefore, seems to be particularly effective in distracting the exerciser away from his or her perceived exertion and associated discomfort (Edworthy & Waring, 2006). Szmedra and Bacharach (1998) analysed music's effect on 10 well-trained men running at a predetermined speed at 70% of their VO_2 max for 15 min. They found that perceived exertion was 10% lower when participants listened to music, especially after the sixth minute of exercise. Women in Macone et al.'s study (2006) who were instructed to run until exhaustion at a predetermined pace, reported having more fatigue after exercising to music, most likely because in the music condition they continued exercising for a longer time. In Brownley et al.'s study (1995), however, RPE in trained participants was lowest where there was no music, while untrained participants' RPE was lowest during the fast music condition. These results suggest that listening to fast, upbeat music during exercise may be beneficial for untrained runners but counterproductive for trained runners, as it may disrupt their ability to maintain an internal focus.

Edworthy and Waring (2006) found no significant effects on RPE scores between their five conditions of fast/loud, fast/quiet, slow/loud, slow/quiet and no music, although a pattern was observed in which participants' RPE were highest in the fast music and no-music condition and lowest in the slow music conditions. The RPE for fast/loud music would be expected to be highest because this was the condition where participants exerted themselves the most. Conversely, even though the RPE for the no music (control) condition was also high, participants did not particularly exert themselves. This suggests that, in the absence of external stimulation, participants focused more strongly on their own efforts and perceived them to be higher than they were (Edworthy & Waring, 2006). Practically speaking, the value of this evidence lies in the fact that music, as an external source of stimulation, can distract an individual from unpleasant feelings such as pain and fatigue. However, in this study, participants' fitness level, training and exercise experience were not taken into account, which may have been factors that influenced their RPE responses.

Overall, it appears that benefits to RPE are not guaranteed when music accompanies exercise. Instead, it appears that the specific combination of activity, participant and music is important in determining RPE effects. In particular, it is uncertain whether elite performers would respond in the same way as untrained participants, in terms of reporting decreased RPE when exercising to music.

2.6 Effects of music on physiological functioning

Music can induce a state of relaxation by inhibiting specific enzymes and hormones that cause fatigue, such as acidosis (Szmedra & Bacharach, 1998). Such a relaxation response likely benefits overall performance and its enjoyment, particularly during higher intensity exercises. Szmedra and Bacharach (1998) investigated the relaxation response during performance by comparing 10 healthy trained males during two 15-min running sessions (on a treadmill) at 70% VO_2 max. In the first training session, participants listened to classical music, while no music was played in the second condition. The physiological measures that were observed as part of the relaxation response were plasma lactate, norepinephrine, heart rate and blood pressure. Perceived exertion was also measured in both trials. The study found significantly lower heart rate, systolic blood pressure, RPE and levels of lactate during the music condition. In addition to the direct effects on a physiological level, the results suggested that music has the ability to influence performance psychologically by reducing feelings of fatigue even though the same effort is applied. How an individual is feeling can be altered by a myriad of internal and external events, such as changing thought processes and/or actual events that may occur which can shape thought processes and subsequent behaviours. This is known as the ABC model (where ‘A’ is action, ‘B’ is behaviour and ‘C’ is consequence), which emphasises that all three factors have the power to affect each other (Ellis, 1991).

Although, some studies have found that sedative music can reduce heart rate (e.g., Ferguson, 1994), the results documenting the effects of stimulative music on physiological arousal have not been well-established. Music can benefit performance if more work is done for the same amount of perceived effort and particularly if there is an increased efficiency in oxygen consumption. Heart rate was significantly lowered in dart-throwing performance in a study by Dorney, Goh, and Lee (1992). Furthermore, a study by Bacon, Myers, and Karageorghis (2008) measured physiological changes in work economy using synchronous and asynchronous music. Participants cycled for 12 minutes at 70% of their maximum heart rate and benefits in oxygen consumption showed a decrease in 7% when the tempo of the accompanying music matched the pace of the participant.

There have been several studies that have also reported an absence of arousal changes in regards to music use. No differences in HR were found when sedative and stimulative music was used prior to a maximal cycling test (Coutts, 1965). Similarly Lee (1989) did not find changes in arousal as measured by HR in a study looking at the effect of varied tempo and genre tracks on submaximal treadmill running in comparison to a no-music condition. Johnson and Siegel (1987) also tested for benefits of music on HR during a 5-minute treadmill running bout and found no increase in arousal compared to a control condition or completing an arithmetic task prior to performance. Other studies yielding no physiological effects were conducted by Boutcher and Trenske (1990), Schwartz and colleagues (1990), and others. Schwartz and colleagues (1990) measured changes in HR, oxygen utilization, and blood lactate during a cycle ergometry test at 75% VO_2 max using stimulative music and no-music conditions. No significant differences were found. Boutcher and Trenske (1990) also found no significant changes to HR at different workload intensities on a cycle ergometry test even when the music was self-selected by the participants. Similarly, Patton (1991) found no significant physiological changes in a study which tested preferred music vs. non-preferred music.

Others who have researched the effects of music on physiological functioning with undocumented benefits include Ferguson (1994) and Uppal and Datta (1990). Ferguson (1994) used a cycle ergometer test to observe changes to HR and blood pressure (BP) in response to stimulative and sedative music. Though there were some documented changes in response to the sedative music, no significant changes were reported. Uppal and Datta (1990) found similar results. Music was found to have a significant impact on BP, but there were no significant changes in HR. Ellis and Brighouse (1952) looked at the heart rate and breathing responses to music and found that, at a statistical level, respiration was affected but heart rate was not. Furthermore, the type of music used was a factor influencing responses. When jazz music was used, breathing increased and when a “dynamic classical” selection was used, breathing increased even more. When looking at the effects of music on the galvanic skin response

(GSR), participants in three different music conditions described as “exciting”, “neutral” and “calming” showed a significant change in GSR in response to the exciting music, a lesser effect in response to neutral music and the lowest effect in response to calming music.

The influence of music tempo has frequently been documented with regard to its effects on heart rate (e.g., Iwanaga, 1995a, 1995b; Karageorghis, Jones, & Low, 2006; North & Hargreaves, 2008). For example, Iwanaga (1995a) conducted a study where participants were asked to regulate the tempo of a track according to their preference and concluded that participants tended to adjust tempo so that it was close to their heart rate, although LeBlanc (1995) criticised this conclusion by pointing out that participants would have to report the same preference during both an at-rest and exercise activity for such conclusions to be valid. However, it is likely that there may be a link between preferred tempo and heart rate when selecting musical pieces at rest.

Based on findings collectively, it appears to hold true that including fast/loud music in the exercise programme of untrained individuals should produce a corresponding increase in physiological responses and may enhance optimal exercising (Edworthy & Waring, 2006). The inclusion of slow, quiet music should be considered for individuals if they wish to reduce physiological responses, which may help individuals prolong exercise endurance. Additionally, slow, quiet music could be utilized by individuals who need to maintain a lower heart rate due to a medical condition or have been advised to exercise at a moderate pace (Edworthy & Waring, 2006). Overall, however, it can be concluded that evidence in support of music having a beneficial effect on physiological functioning is somewhat limited.

2.7 Effects of music on performance

One of the most desirable outcomes of any music intervention would be noticeable improvements in performance. In 1995, the benefits of music on explosive performance were demonstrated by Hall and Erickson (1995) with motivational (preferred) music leading to faster times in a 60 yard running test. The same benefit in performance was illustrated by Simpson and Karageorghis (2006). Using music that was synchronised to each runner's stride, running times showed improvement in a 400 m run in comparison to a no-music condition. Motivational music can also lead to benefits in endurance performance, as evidenced in studies by Ciccomascolo, Finn, Barbaric, and Rinehardt (1995), Copeland and Franks (1991), Elliott et al. (2004), Karageorghis and Jones (2000), Crust and Clough (2006), Matesic and Comartie (2002), Schwartz et al. (1990), and others as reviewed below.

Szabo and colleagues (1999) used symphony (classical) music at different speeds in a study investigating musical as a motivator in cycling performance. Twelve males and 12 females participated in the study by cycling to exhaustion with no music, slow music, fast music (music that was twice as fast as the music in the slow condition), a slow-to-fast music variation and fast-to-slow music variation. In the varying speed conditions, the music tempo was changed when the participant's heart rate reached 70% maximal reserve. Results showed that the musical variation condition, whereby the tempo was increased from slow to fast, led to a statistically significant increase in work output. Given that the completion of the workload was determined by terminal exhaustion, the message that can be inferred is that music has the ability to alter perceptions of tiredness and prolong activity.

In short-duration activities, the ergogenic effects of music have been assessed using a grip strength test. Results demonstrated that grip strength can increase if stimulative music is played prior to performance (Karageorghis, Drew, & Terry, 1996). Further, in a study by Rendi, Szabo, and Szabo (2008), music with varying tempi, were tested against no music on a 500 m rowing test. Slow music, with a tempo of 72-76 bpm, resulted in faster completion times with a decrease of about 1.5 seconds in comparison to the no-music condition. Music with the fastest tempo, ranging from 144-152 bpm, yielded an even greater decrease in completion times of 2.1 seconds in comparison to the no-music trial. The fastest music was also associated with an improvement in stroke rate of 8 strokes per minute.

In 2007, Elliott demonstrated the benefits of music on performance comparing effects of different music speeds. Participants were tested in a work output activity that was accompanied by music and no-music conditions. Of the music conditions, slow music averaged to 100 bpm, moderately fast music was approximately 140 bpm, and fast music was averaged about 180 bpm. Results showed greater benefits when moderately fast music was used in a 20 min cycling test, yielding an increase in performance of 12% in comparison to the no-music condition, and also showing better results than the other two music conditions.

At least two studies have used the Wingate test to assess effects of music on supramaximal performance. In Eliakim, Meckel, Nemet, and Eliakim (2007), fast tempo music was played during a 10 min warm-up session prior to the test. The benefits of the stimulative music were compared to participants completing the test following a no-music warm-up. Stimulative music demonstrated a positive effect on performance by yielding a 3.7% increase in power output, compared to performance after completing the peak power output test without music (. By comparison, another study using the Wingate test showed no benefits of music (Pujol & Langenfeld, 1999).

Research examining different musical tempi confirms that this element is one of the key considerations when selecting music for performance enhancement. Karageorghis et al. (2006) showed that music can have different effects on performance through a design using treadmill-walking activity with male and female undergraduate participants and changing the tempo of the music during treadmill- at different walking intensities (40%, 60% and 75% maximum heart rate). When music was tested at higher exercise intensity, more benefits were derived from higher-paced music, or when the music tempo was increased. In 1999, Szabo et al. similarly demonstrated that when tempo was increased during a graded cycle ergometer test, more work was produced than when the music was played at a uniform tempo. In the latter scenario, the following was true regardless of whether the tempo was considered slow or fast. The former has been referred to as a contrast effect, indicating the benefits that are derived from the contrasting experience as a result of the contrast of the gradual increase in tempo.

Studies have also investigated different intensity exercises with different musical tempi. For example, Karageorghis, Jones, and Stuart (2008) evaluated effects of six exercise intensities and four types of musical tempi ranging from slow to fast. Results showed a preference for medium tempi music at the fourth and fifth intensity workout, which corresponded to a maximum heart rate of 70% and 80%, respectively. These results indicated that the more specifically the musical selection is matched to the desired output of training intensity, the greater the benefits that can be observed on training performance. This notion has been supported by Terry and Karageorghis (2006) and is relevant to studies using music for performance enhancement as measured by work output.

Brownley et al. (1995) studied the effects of no music, slow music, derived from commercially-marketed stress management selections, and fast music, including contemporary pop, rock, and movie sound track selections within a tempo range of 154-162 bpm. Participants listened to the same sedative music tape, but were given a choice between two fast music tapes in order to incorporate some degree of individual preference for music style. Results showed that untrained participants reported more positive affect compared to trained participants while listening to fast music during low and high intensity exercises, suggesting again that listening to music during exercise may be beneficial for untrained runners, but not necessarily for trained runners.

Although we have yet to get a good understanding of the mechanisms underlying the effects of music, Rejeski (1985) parallel processing theory posits that music would be effective at altering physical and psychological states of performance primarily at low-to-moderate exercise intensities. Yamashita, Iwai, Akimoto, Sugawara and Kono (2006) previously confirmed the benefits of music on RPE at low and moderate intensity exercises. Studies by Szmedra and Bacharach (1998), Potteiger, Schroeder and Geoff (2000) and White and Potteiger (1996) also yielded favourable results regarding the benefits of music at moderate intensities. Although Dyrlund and Wininger (2008) showed no significant benefits of preferred and non-preferred music on low, moderate and high intensity treadmill running, increased dissociation was still reported by participants in preferred music conditions. However, in this study, it was the researchers, and not the participants, who manipulated the music that was selected for the ‘preferred’ music conditions.

Three consecutive studies by Karageorghis and colleagues (Karageorghis, Jones, & Low, 2006; Karageorghis et al., 2008, 2011) showed that fast music is preferred during high intensity workouts. Of particular relevance to the effects of music on heart rate, tempo has been linked to increases in physiological functioning. These results were tested in a steady-state running condition of 8.8 km/hr for all participants (Birnbaum, Boone, & Huschle, 2009). Unfortunately, this speed did not take into account the differences in strenuous effort that may have been required across participants, who could have found the task easy or difficult. The design also did not take into account that some participants could have intended to run at greater speeds with greater levels of arousal which would not have been possible at a fixed treadmill speed. Some studies that have tested music conditions in high intensity activity were unable to demonstrate any significant benefits from music (Macone et al., 2006; Schie, Stewart, Becker, & Roger, 2008; Tenenbaum et al., 2004) while music conditions were found to increase performance times in exhaustion trials in other studies (Atkinson et al., 2004; Bharani, Sahu, & Mathew, 2004; Nakamura, Pereira, Papini, Nakamura, & Kokubun, 2010).

Studies looking at the effect of music on self-paced running exercise found improvements in work output (Elliott, 2007; Matesic & Cromartie, 2002). Waterhouse, Hudson and Edwards (2010) found that the benefits of music increased the distance pedalled on an ergometer when the tempo was increased by 10%, and the perception of effort increased as well. This indicated that participants were aware of the increased effort. The opposite was found to be true in Elliott’s (2007) study, where participants in a music condition increased the distance pedalled without increasing RPE compared to the control condition. In a self-paced run study, Barwood, Weston, Thelwell, and Page (2009) found that coupling motivational music, as assessed with the third iteration of the Brunel Music Rating Inventory (BMRI-3), and motivational films, defined as sporting success footage, yielded further distances in running trials without an increase in RPE compared to a no-music condition. The study was limited to six participants, although the music intervention used was externally valid, novel and, thus, of future interest.

2.8 Summary of Music Research in Sport and Exercise

The benefits of music have been documented in behavioural, psychological, physical and performance assessments. In particular, music has demonstrated greater benefits on psychological states and performance indices when it is considered to be motivational, in particular when music is self-selected. Some studies (e.g., Dyrlund & Winniger, 2008) have imposed the music used in the preferred music condition rather than letting participants use self-selected music. Self-selected music may impact performance more than researcher-selected music because it is the participant rather than the researcher who will be stimulated by its results. Hence, self-selected motivational music is generally advocated over researcher-selected music (e.g., Pates, Karageorghis, Fryer, & Maynard, 2003). Findings highlighting the efficacy of self-selected music as a tool to optimise responses to everyday activities have been demonstrated by Cassidy and MacDonald (2009), where higher degrees of inaccuracy, highest perceived distraction, lowest liking, enjoyment and appropriateness, and increased anxiety were reported while listening to researcher-selected music during a simulated driving performance task.

With respect to psychological benefits, music appears to positively affect elements of mood, particularly anger, fatigue, and depression. Music can also affect motor performance via the benefits it provides to endurance and increases in workloads. With regards to motor learning, music can enhance skill acquisition by regulating internal pacing. Further studies in this area would strengthen the literature supporting this positive evidence, such as studies with more consistent methodologies. For example, past studies may have chosen to employ music with no lyrics (Macone et al., 2006), neglected to specify tempo/track bpm (Szmedra & Bacharach, 1998) or allowed participants to bring in their own music during experimentation (De Bourdeaudhuij et al., 2002), making results harder to replicate.

Other studies have questioned the benefits of music (or lack thereof) in performance, such as those mentioned by Brownley and colleagues (1995), De Bourdeaudhuij and colleagues (2002), and Macone and colleagues (2006). Karageorghis and Terry (1997) argued that null findings can be explained largely by flawed or inconsistent research designs, such as using researcher manipulated music (see also Karageorghis & Priest, 2012). Edworthy and Waring's (2006) study, for example, did not account for participant fitness level, training and experience in their study looking at RPE, possibly explaining a lack of significance in their results. Pujol and Langenfeld (1999) did not find any differences in performance when music was used to enhance performance on the Wingate test. A possible explanation for the lack of benefit observed in this study could relate to the extreme physical effort required in the task. In other words, at high intensity work-outs, it is hard to extract the benefits of music because the physical sensations are overwhelming and demand maximum attention. Thus, attention levels are at their maximum threshold so that the individual becomes unresponsive to external stimuli. For this reason, in research designs where the intended goal of music application is to reduce perceived exertion, it may not be appropriate to assign a music implementation when the activity is at a supramaximal level of strain.

Similarly, Scott, Scott, Bedic, and Dowd (1999) did not observe any positive effects in performance during a maximal 40 min rowing ergometer session. Tenenbaum and colleagues (2004) failed to observe significant benefits using music on two running conditions. Participants ran at 90% of their maximum oxygen uptake capacity. Absence of benefits of music was also found when participants ran maximally in an outdoor setting for 2.2km. In both examples, the intensity of the activity was very high and, in such case, the body's physiological response to pain and/or exhaustion may have made it difficult for the participant to attend to the musical stimuli. In summary, it is still unclear whether music, especially synchronous music, can have a beneficial effect on performance and other variables of interest during maximal exercise, especially among elite athletes competing in national and international competitions.

CHAPTER 3: STUDY 1

3.1. Introduction to the programme aims

Previous studies have investigated the benefits of music in a wide variety of sport and exercise settings. Most of the existing studies have looked at music for its psychological and performance benefits but many of those studies had limitations with regards to how the musical selections were made. The current research aimed to address this limitation by selecting music in a way that was sensitive to the characteristics of the individual participant, matching musical selections to the preferences and cultural background of the athletes and synchronising musical tempo to the stride rate of individual athletes.

Few previous studies have investigated elite athletic populations. In elite performance, the difference between silver and gold medals can often be measured in 100ths of a second. Elite coaches want to know whether the benefits they can expect from music are just improved feelings or are, in fact, objective benefits that can be observed in performance. Coaches are also interested in whether music can be delivered universally to all athletes as a group during group training. Essentially, the coaches are interested in knowing the practical applications of the music in both training and competitions. Other control procedures will be implemented that add consistency to the activity itself, thus making any change in performance more easily attributable to music. These included keeping the time of day of the running tests constant across all performers, monitoring food intake so that it does not vary, and maintaining constant ambient temperature in the test environment.

Elite athletes are difficult to recruit for research purposes. Athletic performance is sensitive to changes in routine, making elite athletes and their coaches apprehensive that performance may be threatened as a result of participating in research. Also, elite populations can be difficult to access because their schedules are already cramped, particularly during competition season. Thus, recruiting elite populations to test the benefits of music is very challenging. However, despite the hesitation to participate, all of the elite athletes and coaches contacted for this study were extremely interested in the underlying principles of the research and the findings from previous studies.

3. 2. Recruitment and selection of elite athletes at the QAS

The present study was sponsored by the Queensland Academy of Sport (QAS), a Queensland Government-funded organisation, whose aim is to develop Queensland's elite athletes and identify and train developing athletes. The main role of the QAS is to ensure that Queensland representation both internationally and domestically remains high. The QAS, whose philosophy is "athlete-centered, coach-driven and service-supported", provides support to over 600 athletes in 22 sports. A large number of elite athletes, developed within the QAS, have gone on to win national and major international competitions, such as the Olympic Games, Commonwealth Games and World Championships. QAS scholarship holders can access top level coaching and support, including sport science, strength and conditioning, medical, career and education, and financial support for training and competition. The QAS facility has a fully equipped gym, a sport science laboratory, an on-site medical centre with a rehabilitation and training pool, and wet therapy area (ice baths, hot spa, sauna and cold plunge pool).

The QAS Sport Science unit is accredited by the National Sport Science Quality Assurance Programme which is, in turn, initiated and overseen by the Australian Institute of Sport. Such accreditation requires stringent testing protocols to support both indoor (laboratory) and field testing. Some of the data that can be collected using the equipment available within the unit, and its highly qualified staff, is of particular interest to the present study, including aerobic capacity (VO_2 max) and anaerobic threshold. The support of the staff and services provided by the QAS were vital in accessing very expensive equipment and the availability of the staff in monitoring the use and functionality of the equipment was invaluable and can be seen as one of strengths of the present study.

The QAS Centre of Excellence (CoE) for Applied Sport Science Research exists to promote research that is designed to assist athletes and coaches with results that deliver enhanced performance. In doing so, its role is to encourage applied research in sport science, to supply scholarships to postgraduate students enrolled in universities in a sport science field, and to fund the equipment and the development of technology to assist elite athletes. The CoE supports research in coaching, injury management, metabolism and technology development that can improve elite sport practices. The CoE sponsored the present research by meeting all research costs and providing a PhD scholarship.

Prior to recruiting the athletes, the researchers engaged in several meetings with the Centre of Excellence Director, coaches of the chosen team and all support staff. The purpose of the meetings was to “pitch” the study as a project whose benefits would interest not only researchers and elite athletes in general, but each of the athletes who would be participating, and also their coaches. During the meeting, hypotheses were discussed based on previous and expected data and the time required for participation for this study was detailed. Furthermore, incentives in the form of food vouchers were provided to encourage participation. All participants received a copy of the music used which could be useful for them during training, plus a report of their personalised data. Once the coaches were supportive, athlete participation quickly followed with a consent form and another meeting with the team to formalise expectations and procedures for this study.

The participants that were chosen, from the variety of sports that were considered, were all members of the QAS elite triathlete team. The team was composed of both junior and senior elite status triathletes, with national and international success in major competitions, including World Championship gold, silver and bronze medallists. Triathlon was chosen as a suitable sport for several reasons. Firstly, incorporating swimming, cycling and running into their training and competitions, triathlons can be regarded as some of the fittest athletes in the world. Secondly, many of the athletes in the QAS group were ranked very highly in their sport, which motivated the researchers in their quest to test the benefits of music using elite athletes. Thirdly, the running component of their training is one of easier activities in which to measure musical benefits in a repetitive task.

3. 3. Participants

Participants were 11 Australian male (n = 6) and female (n = 5) elite triathletes, ranging from 17 to 24 years of age, competing and holding titles in national and international junior, under-23 and open competitions. One participant qualified for the London Olympics 2012. Participation was voluntary but encouraged by their coach, following a presentation by the authors on the expected benefits and protocol. All participants corresponded to the desired population in terms of the level and experience in elite sport.

3.4 Musical selection

Musical selections were individualised considering the motivational qualities of the music, rated by the participant and the synchronicity potential of the musical selection. Participants emailed the researcher a list of tracks that motivated them to run. The researcher downloaded the tracks and assessed their synchronicity to the participant's pace using *Virtual DJ* (see Appendix B). A ± 4 beats per minute (bpm) range within the participant's cadence was used for assessing synchronous tracks. Preliminary track lists were developed for the participants' convenience, displaying names of artists, tracks and musical genre to assist their decision making, rating all tracks on a 1-10 scale, with 1 being not motivational to run at all and 10 being motivational in every possible way. A rating of 7 or above was considered motivational for the purpose of this study. The music-led condition also incorporated the synchronicity of the music with an extra increase in tempo in the latter stages of the run. Tracks selected for the increased tempo were used to lead the change of pace that was not perceptible to the participant so each track was modified from its beginning. Participants were allowed to change their minds regarding their playlist on the trial day so long as each track was synchronous to their trial.

3.5 Measures and materials

The measures and materials used in this study included the Brunel Music Rating Inventory-2 (BMRI-2), the Feeling Scale, the Brunel Mood Scale (BRUMS), the Borg Scale, a food diary, a Payne wide-bodied treadmill fitted with Optojump, gas analysers, blood sampling techniques, and various musical tracks.

3.5.1 The Brunel Music Rating Inventory-2 (Karageorghis, Priest, Terry, Chatzisarantis, & Lane, 2006). The BMRI-2 (see Appendix D) assesses the motivational properties of a track using six items of relevance (rhythm, style, melody, tempo, instruments, and beat of the music track). Participants rate the track using a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Total scores range from 6-42. The Brunel Music Rating Inventory (BMRI) was originally developed by Karageorghis et al. (1999) and has since been revised in two further iterations (BMRI-2: Karageorghis et al., 2006; BMRI-3: Karageorghis et al., 2008). The BMRI-2 is an advanced version of the BMRI, with improved psychometric properties. The BMRI was designed to help experts, such as aerobics instructors, select music for exercise-related tasks. The BMRI-2 has been designed, more specifically, as a valid and internally consistent tool which can be used both by experts *and* participants. It is easier to use and enables researchers to standardise music selection in research designs with exercise-related activities, such as running.

3.5.2 The Feeling Scale (Hardy & Rejeski, 1989). The Feeling Scale (Appendix F) requires respondents to rate how they are feeling on an 11-point scale, ranging from +5 ‘Very Good’ to -5 ‘Very Bad’, with 0 representing neutral feelings. Hardy and

Rejeski (1989) hypothesised that an individual could feel both good and bad feelings during the same bout of exercise. The Feeling Scale, with its simple 1-item structure, facilitates the assessment of in-task feelings *during* performance. The Feeling Scale has demonstrated satisfactory psychometric properties in exercise settings (Karageorghis, Vlachopoulos, & Terry, 2000). Previous studies that have used the Feeling Scale successfully in music-related studies include those by Brownley et al. (1995), Edworthy and Waring (2006), Karageorghis et al. (2009) and Rose and Parfitt (2008).

3.5.3 The Brunel Mood Scale (Terry, Lane, Lane, & Keohane, 1999; Terry, Lane, & Fogarty, 2003). The Brunel Mood Scale (BRUMS) has 24 items, measuring the extent to which an individual may be feeling anger, confusion, depression, fatigue, tension and vigour. Each of the mood descriptors is rated on a 5-point Likert scale, where 0 is ‘Not at all’, 1 is ‘A little’, 2 is ‘Moderately’, 3 is ‘Quite A Bit’ and 4 is ‘Extremely’. Other mood profiling measures, such as the Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1971), upon which the BRUMS is based, were not considered appropriate because the POMS is a 65-item checklist that takes much longer to complete. Further, the POMS has not been validated on minors (under 18 years of age) nor athletes. The 24-item BRUMS (see Appendix E) takes less than 2 minutes to complete and has been tested rigorously for validity and reliability in both adolescent and adult populations (Terry et al., 2003).

3.5.4 Ratings of Perceived Exertion (RPE; Borg, 1970). Borg’s RPE scale was developed to assess perceived exertion in a series of studies, involving psychophysical and physiological testing. RPE summarizes exertion levels between rest and maximum effort on a scale of 6-20 (see Appendix G). This scale is one of the most commonly-used indices for monitoring the points during endurance tests where changes in perceived exertion occur. Research on rates of perceived exertion (RPE) has demonstrated correlations between an athlete's rate of perceived exertion and their heart rate, lactate levels, VO_2max and breathing rate (Borg, 1982). Numerous studies have demonstrated the suitability of these measures for assessing perceived effort for physical work in music-related studies (e.g., Edworthy & Waring, 2006; Karageorghis et al. 2009**).**

*3.5.5 Food Diary***.** A food diary was used to ensure, for example, that any mood change could not be attributed to a breakfast that delivered different levels of sugar or potentially mood-elevating substances. The food diary (see Appendix J) consisted of an A4 sheet of paper where participant listed the quantity of each food/drink item consumed and any additional comments regarding that meal, such as "very hungry after training", "pre-race meal" or "1 hr 20 min run" regarding the training session that occurred in between meals.

3.5.6 Music Selections. All participants emailed to the researcher a list of their favourite tracks to run to or tracks that would motivate them to run. After having received individual baseline stride rate data from the team physiologist, all tracks listed by participants as motivational were downloaded, as well as other tracks with similar tempi from different genres. A range of musical genres was sought to give the participants the maximum range of tracks from which to select their motivational and neutral (or *oudeterous*) music. Participants' stride rates, or cadences, were within the range of 158 bpm to 185 bpm. Due to their very high paced cadence, and the non-availability of such high tempo music, it was necessary to choose music the tempo of which was half the participant's cadence, meaning that participants ran two strides to the beat. Thus, the tempo of the music accommodated the range of 79 to 94 strides per second. Most of the music fell within the mid-80s bpm range. A list of the music tracks used in Study 1 is contained in Appendix A.

At this point, the downloaded track list was emailed back to participants and the BMRI-2 was used to provide a numeric value for the motivational qualities of each track. Any track with a BMRI-2 rating of 36-42 was considered motivational. Tracks with a BMRI-2 rating of 18-30 were considered to be neutral. Tracks rated <18 or 31-35 were not used because they could be considered either de-motivational (<18) or almost motivational (31-35) rather than neutral. Motivational ratings were not queried by the researchers, given the personal meaning and associations ascribed to specific tracks by individuals. Using this method, an individualised playlist of tracks was developed for each participant to be used during laboratory testing. Each participant was provided with their customised digital playlist once participation was completed.

The Apple software programme *i*Tunes was used to purchase and download tracks. These tracks were pre-recorded onto a folder using the software programme, *Virtual DJ*. This programme allows for tracks to be downloaded, modified, and recorded. *Virtual DJ* also allows for digital mixing at a professional level, allowing the user to cue, adjust pitch, scratch and loop amongst other things, and the console, located in the middle, is where further changes can be made, such as volume control and transitioning between tracks. Moreover, *Virtual DJ* immediately reads the bpm of each track as soon as it is uploaded onto either of the two top panels (see Appendix B).

The instant bpm reading is one of the key features of using this programme. Though many websites are available where an individual interested in track tempo can see which tracks match their desired bpm, often the reported tempo is inaccurate. The researcher found that, although a track may have been listed as a specific tempo on a website, the website bpm was not necessarily the bpm that was registered by the *Virtual DJ* programme. In some instances, the track differed from the website tempo by 10 bpm. This discrepancy would have been critical in affecting performance because tracks cannot be modified beyond ±4 bpm of their original tempo without distorting the musical properties of the original version. For example, if a track's tempo is 80 bpm, the revised tempo can range from 76 to 84 bpm. If a track were to be modified past that range, the audio properties would be distorted. In the event that changes beyond this range were made to a track that was considered motivational, the track might not have been recognised by the listener as the original version and the differences would have been quite distracting and potentially detrimental to any possible benefits that might have been yielded by that track.

The *Virtual DJ* programme has other strengths. For example, in some cases, the participant requested a live version of a particular track, with a slightly different tempo to the recorded version. *Virtual DJ* not only allows the user to confirm the bpm of the live version, but also allows the user to trim the applause or long introduction by fading into the track's introduction at a later start, closer to the beginning of the lyrics. The software allows for two tracks to be playing simultaneously so that a recording can be made without any gaps in between tracks. It was considered by the researchers to be a very versatile and user friendly application programme that was appropriate in downloading tracks for this study and also for allowing the participants to subsequently refine their individual playlists.

3.5.7 Treadmill Testing. A Payne wide-bodied treadmill (Stanton Engineering, Sydney, Australia) fitted with Optojump (Microgate, Bolzano, Italy), available in the QAS Sport Science Laboratory, was used during all running trials to control the speed at which each participant ran. The Optojump is a small electronic strip that is attached to the side of the running belt using a light sheet to capture the foot movement of the participant. It measures air time (how long the foot is in the air) and how long the foot stays on the ground. The Optojump was used before the trials to collect all participants' stride rates for each of the different running velocities.

3.5.8 Measurement of Oxygen Consumption. An Applied Electro Chemistry Moxus metabolic cart (AEI Technologies, Pittsburgh, PA) was used to measure oxygen consumption and carbon dioxide emission. Each of the gas analysers was calibrated before each session to ensure accurate data collection. This was done by the QAS laboratory physiologists and the researcher. Gas analysers were connected to a head mask placed over the mouth of the participant with nostrils sealed using a nose clip. Oxygen consumption and VO_2 max were assessed during testing. VO_2 max is essentially a measure of endurance performance by assessing the body's maximum rate of oxygen consumption during exercise, in millilitres of oxygen consumed per minute, divided by body weight. Wikipedia lists the average VO_2 max value for young untrained males to be about 45 ml/min/kg compared to the VO_2 max of world class endurance athletes of about 80 ml/min/kg. VO_2 max should be considered as an indication of aerobic fitness that, when used in conjunction with blood lactate threshold, helps to determine optimal training strategies. Use of this apparatus for monitoring oxygen consumption is acknowledged as a potential distraction for participants during data collection.

3.5.9 Measurement of Blood Lactate. Blood lactate was collected using blood sampling techniques recommended by the Australian Sports Commission. Lactate testing is one of the most frequently-used ways of measuring and predicting athletic endurance performance. Training used to increase lactate threshold is a widely used method of improving performance at high levels of intensity. Essentially, lactate threshold measures the point at which the lactate build-up in the blood exceeds the lactate removal. Lactate removal is generally possible at any value below 50% of an individual's VO_2 max. The average person reaches their lactate threshold at about 60% of their VO_2 max value. Amateur athletes reach their lactate threshold at 65%-80% of their VO_2 max and elite endurance athletes reach lactate threshold at 85%-95% of their VO_2 max value. Once the lactate accumulates and is no longer being absorbed, the body rapidly experiences fatigue. At this point, the individual is usually forced to stop.

Lactate was measured using blood samples taken from the earlobe. The QAS physiologist performed this measure for athletes at the start and end of each trial and at points during the trial. Blood lactate was collected using a sterile lancet. An earlobe puncture delivered a small sample of blood which was immediately placed on a handheld strip for analysis, in accordance with the Australian Sports Commission approved method for collecting such measures.

Lactate threshold occurs sooner than VO_2 max so it can be referred to as a percentage of VO_2 max. This measure is of particular interest to endurance athletes and their coaches and, if music were able to contribute to increasing lactate threshold, this would be of particular benefit to any endurance athlete. Lactate threshold can also be used to determine how to train in terms of pace regulation and what pace best suits a particular endurance run. Coaches and athletes report that athletes often do not pace themselves properly and therefore burn out quickly at the start of an event. The purpose in measuring lactate threshold is that it is indicative of the onset of fatigue and exhaustion.

3.6 Procedure

The exact protocol used was unique in its application. All participants were required to come into the QAS laboratory for a baseline running test, using a standard protocol used by Triathlon Australia, to determine VO_2 max values, the speed at which each individual reached blood lactate threshold and each participant's individual stride rate at various velocities. The baseline test included 4-5 sub-maximal steps (e.g., 12, 13, 14, 16 $km{\cdot}h^{-1}$) each of 4-min duration followed, after a 4-min break, by a rapid ramp to exhaustion commencing 3 $km{\cdot}h^{-1}$ below the final sub-maximal velocity and increasing in velocity then grade every 30 s. The baseline testing also habituated the participants to the test environment.

Each participant completed three test trials (no music, neutral music, motivational music) in counterbalanced order at the same time of day, commencing with a 5-min warm-up at 10-12 $km{\cdot}h^{-1}$, followed by three 4-min periods of submaximal running at progressively faster velocities (e.g., 14, 16 and 18 $km{\cdot}h^{-1}$) with a 2-min break in between. Velocities for the three submaximal running periods equated to approximately 76%, 82% and 87% VO_2 max, for each participant. Finally, after a 5-min break, participants completed a run-to-exhaustion at approximately 110% of blood lactate threshold velocity (99% VO_2 max), adjusted to the nearest 0.5 $km \cdot h^{-1}$.

Running trials were held prior to training on regular training days, which were almost every day, with possibly a weekend break, and all three trials occurred within a two week period, to avoid training effects. If a participant had to cancel a trial, rescheduling was allowed and took place no more than one week following the original date. Participants ran in a randomly assigned trial order by drawing straws after their baseline run. On the day of the first trial, participants arrived and their weight and height measurements were taken. Participants were allowed to stretch a little before completing the BRUMS. Participants then warmed up on the treadmill at any speed below 12 km per hour until they stated they were ready to start. Participants then stepped off the treadmill and blood samples were taken once from their ear before the start of the test and between each running period. The blood samples were used to assess lactate and pH values at rest and intermittently during trials.

Two A4 print-outs of the Feeling Scale and Rate of Perceived Exertion scale were placed in front of the treadmill for participant ratings between trials; participants chose to point at the numbers or verbally express values. Music volume was standardized at 79 dB (ear level) and a stopwatch was used to measure each run to exhaustion bout in all (music and non-music) trials. No feedback was given during the trials and time was not shown to participants during the run to exhaustion.

Music was delivered during testing using a Dell laptop computer with the *Virtual DJ* programme turntables open and ready to be played. The treadmill itself caused some noise disturbance so the ideal volume had to be adjusted slightly during trials. Speakers were placed on a small table in front of the treadmill at chest level so that participants were facing them without the speakers being in their face. Earphones may have delivered the music at a more constant volume so this is acknowledged as a limitation in this protocol. However, a sound meter was used to ensure that all music was delivered at the ideal sound level of 79 dB (North & Hargreaves, 1995). The reason for this is that music at lower volumes may easily fade into the background and any volume greater than 79 dB could distort the pleasure of the listening experience for the participant. The sound meter was carried around to both sides of the participant's ear during the trial to ensure that there were no drops or sudden rises in volume, as is sometimes the case with music that is downloaded from the internet. If participants felt that the music was too loud they could gesture by pointing to their ears very quickly as a sign to lower the music volume.

3.7 Data Analysis

The elite population being investigated inevitably limited the availability of participants. This, in turn, reduced statistical power and the probability of finding significantly different outcomes among the three conditions. Effect sizes (Cohen's *d*) were therefore used in preference to *p* values to quantify differences among conditions, a strategy endorsed by research methodologists and statisticians (e.g., Andersen & Stoové, 1998). Cohen's *d* represents the difference between group means divided by the pooled standard deviation. An effect size of .2 is considered small, .5 is considered moderate, and .8 is considered large (Cohen, 1988).

3. 8. Hypotheses

The following research hypotheses were tested:

1. Running performance would be superior when running in time to music than running without music.
2. Psychological measures (mood responses and feelings) would be more positive when running in time to music than running without music.
3. Rate of perceived exertion would be lower when running in time to music than running without music.
4. Physiological measures (lactate concentration, running economy, oxygen consumption) would be more favourable when running in time to music than running without music.

3.9 Results

Results of Study 1 are shown in Table 3.1, which includes descriptive statistics for all measured variables for each of the three conditions, plus effect sizes for the two music conditions compared to the no-music condition. Results for each measured variable are reported below.

Time-to-exhaustion for the three conditions is shown graphically in Figure 3.1. Compared to the no-music condition, running to motivational music produced an average increase in time-to-exhaustion of 77.55 seconds, an 18% improvement in performance. During the neutral music condition, participants ran an extra 84.55 seconds compared to the no-music condition, a 19.7% improvement in performance. From discussions with coaches, a 30 second improvement in run-to-exhaustion is regarded as significant from a performance perspective.

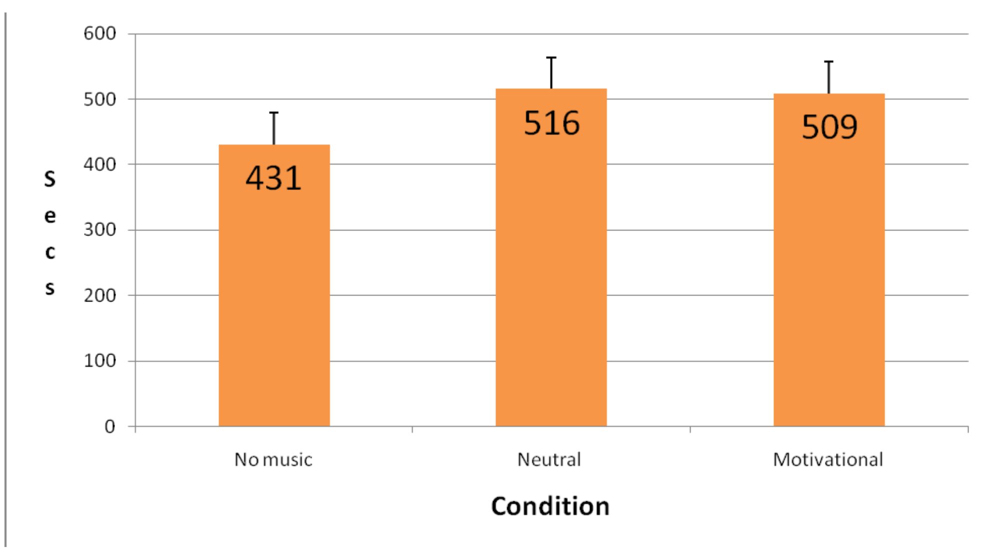

Figure 3.1. Time to Exhaustion for 11 Elite Triathletes in Three Conditions.

Table 3.1

Performance, RPE, and Physiological Data for 11 Elite Triathletes Under Two Music Conditions and a No-music Control. Data Expressed as Mean (Standard Deviation).

	Motivational	Neutral	No Music	Effect Size (*d*) vs No music	
				Motivational	Neutral
Time-to-exhaustion (sec)	509.00 (50.25)	516.00 (47.02)	431.45 (46.15)	.50	.54
RPE -4 min	10.64 (1.50)	10.36 (1.03)	10.73 (1.42)	.11	.39
RPE -10 min	12.00 (1.41)	11.64 (0.67)	11.91 (1.51)	-.09	.19
RPE -16 min	13.09 (1.45)	13.00 (0.87)	13.36 (1.21)	.19	.29
RPE – exhaustion	17.91 (1.64)	17.82 (1.54)	17.73 (2.20)	-.10	-.06
Lactate – pre-test (mmol l^{-1})	1.03 (0.35)	1.02 (0.36)	1.03 (0.40)	-.01	.05
Lactate – 4 min (mmol l^{-1})	1.48 (0.41)	1.47 (0.48)	1.46 (0.42)	-.06	-.02
Lactate – 10 min (mmol l^{-1})	1.49 (0.35)	1.66 (0.48)	1.63 (0.41)	.37	-.13
Lactate – 16 min (mmol l^{-1})	1.99 (0.44)	2.19 (0.62)	2.01 (0.37)	.07	-.34
Lactate – exhaustion (mmol l^{-1})	6.47 (1.69)	6.16 (2.83)	5.94 (2.14)	-.15	-.06
VO_2 -4 min[a] (mL kg^{-1} min^{-1})	46.36 (3.17)	46.24 (2.82)	46.85 (4.00)	.16	.28
VO_2 -10 min[a] (mL kg^{-1} min^{-1})	49.88 (2.97)	49.20 (3.12)	50.13 (4.15)	.07	-.34
VO_2 -16 min[a] (mL kg^{-1} min^{-1})	53.80 (3.09)	52.86 (3.39)	54.33 (4.49)	.13	.51
VO_2 – exhaustion[a] (mL kg^{-1} min^{-1})	63.72 (4.62)	63.04 (5.43)	64.16 (5.32)	.29	.64
Running economy[a] (mL kg^{-75} min^{-1} km^{-1}) h^{-1})	10.12 (0.99)	9.19 (1.68)	10.63 (1.92)	.29	.64

[a]Based on data from 10 participants.

Ratings of perceived exertion (RPE) for all three conditions can be observed in Figure 3.2. Overall, RPE was lowest in the neutral music condition. Effect sizes for the neutral music condition compared to the no-music condition after each submaximal phase (i.e., time points T1, T2, T3) were *d* = .39, *d* = .19, and *d* = .29, respectively. The motivational music also showed a small benefit in perceived exertion in comparison to the no-music condition after the third submaximal phase (*d* = .19).

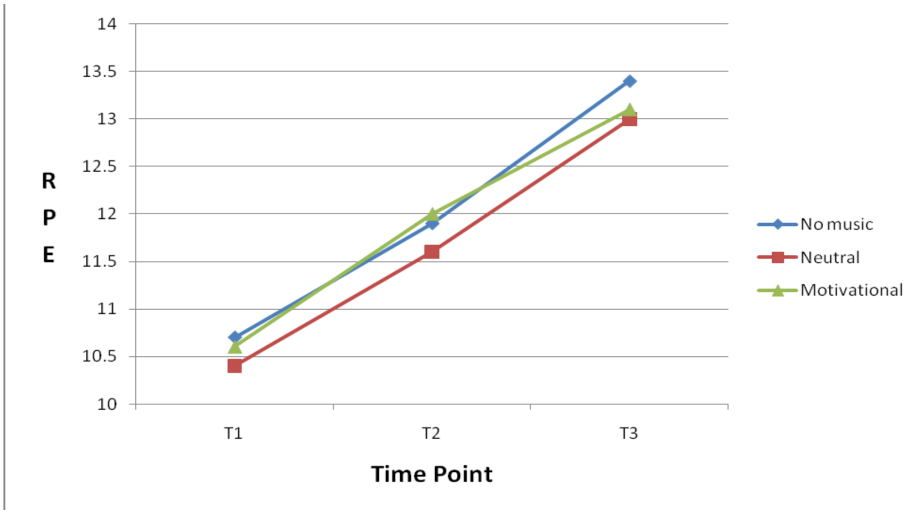

Figure 3.2. RPE for 11 Elite Triathletes in Three Conditions

The next analysis, illustrated in Figure 3.3, looked at the effect of music on the feelings reported by the participants during the running tests, using the Feeling Scale. Overall, positive effects were noticeable for the motivational music condition compared to the no-music condition after the three submaximal phases (*d* = .49, *d* = .60, *d* = .45) and a very large effect was shown after the run-to-exhaustion (*d* = 1.08). Compared to the neutral music, the effect of the benefits observed were moderate after the first running bout (*d* = .49), large after the second (*d* = .78) and very large following the run-to-exhaustion (*d* = 1.23). No differences were present between the neutral music condition and no-music condition. Feelings generally became more negative as testing progressed, most noticeably after the run-to-exhaustion. Unlike the neutral and no-music conditions, motivational music yielded positive feelings throughout the entire duration of the test.

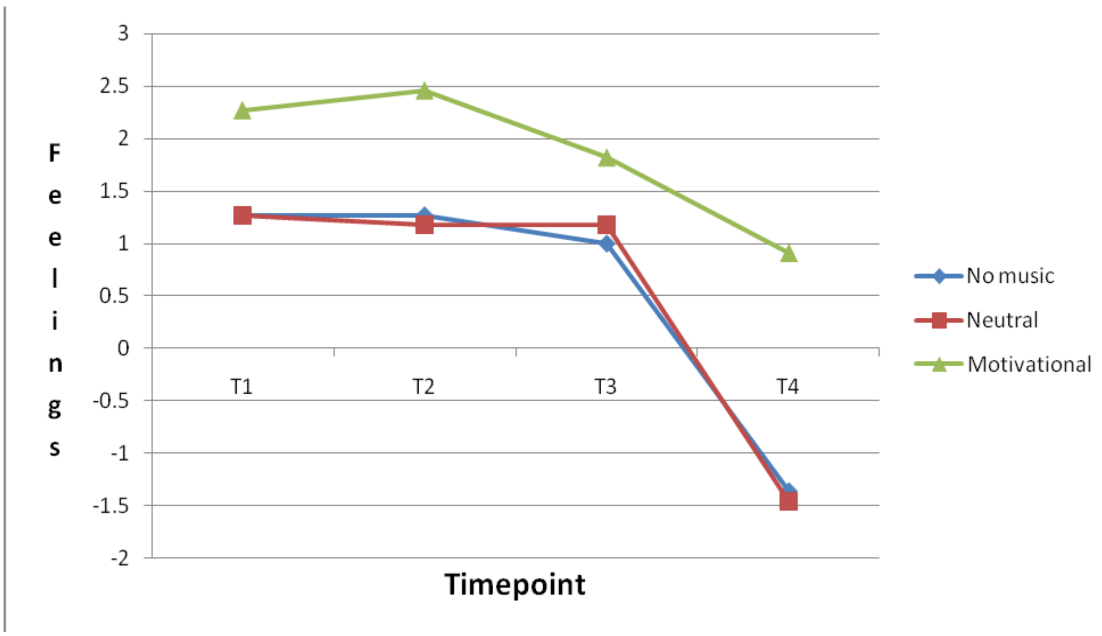

Figure 3.3. Feeling Scale Scores for 11 Elite Triathletes in Three Conditions

Analysis for pre- and post-test mood scores using the BRUMS showed differences across the three conditions for tension, depression, anger, vigour, fatigue and confusion (see Figure 3.4). Visible from pre-test to post-test were increases in depression, anger, fatigue and confusion, and decreases in tension and vigour. In comparison to neutral music and no-music conditions, motivational music showed a greater benefit on tension scores (*d* = .50, *d* = .38, respectively) and limited the increases in depression, anger and confusion, although these differences were small.

Both music conditions yielded lower increases in fatigue scores compared to no music, (*d* = .31; neutral music v. no music, *d* = .43¸ motivational music v. no music), even though more work was completed in the music conditions. Vigour rose in the motivational music condition compared to the other two conditions (*d* = .34; no music v motivational music).

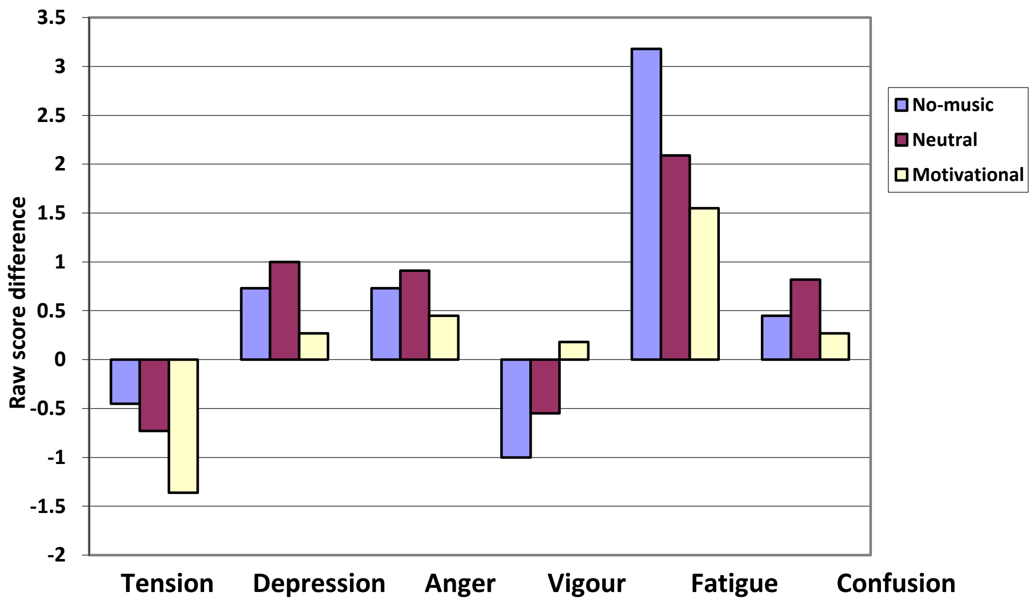

Figure 3.4. Mood Changes of 11 Elite Triathletes from Pre- to Post-Testing in Three Conditions.

The physiological measures in this study were blood lactate concentration, running economy, and oxygen consumption. Figure 3.5 shows that lactate levels varied slightly but generally remained constant across the three conditions at time points 1 and 2, with motivational music being associated with lower lactate levels at time point 3 in comparison to no music (*d* = .37) as well as in comparison to neutral music conditions at time point 3 and after the run to exhaustion (*d* = .57, *d* = .42, respectively).

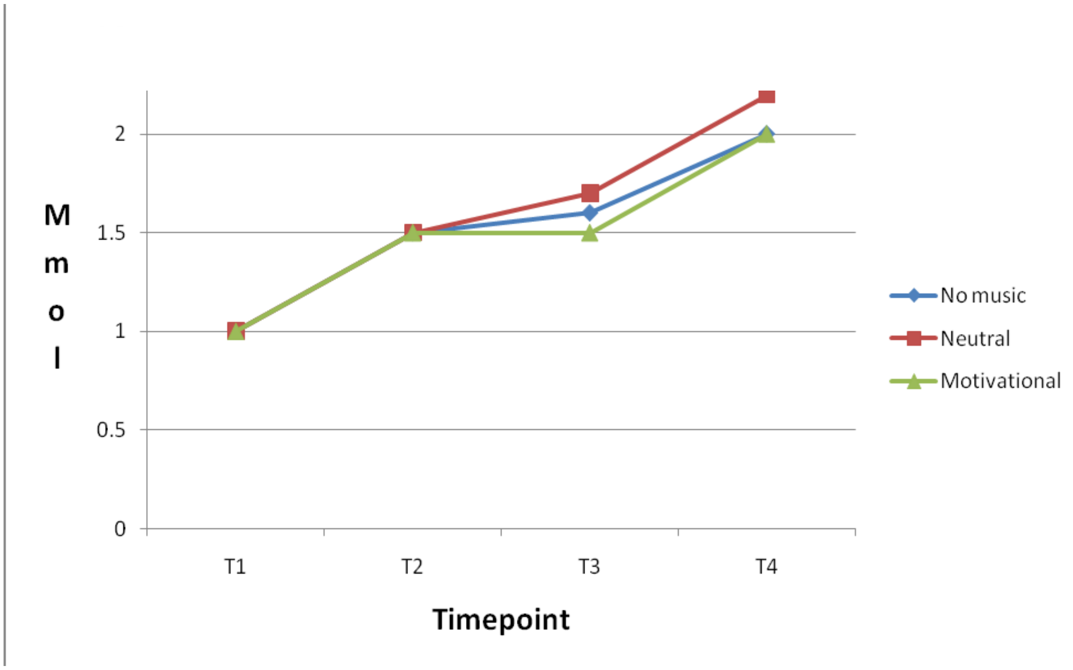

Figure 3.5. Lactate Values for 11 Elite Triathletes in Three Conditions

Oxygen utilization was used to illustrate the differences in running economy amongst conditions (see Figure 3.6). During the three submaximal phases, benefits in both music conditions were observed in terms of running economy, with a small-to-moderate benefit observed in the motivational music (*d* =.29) and a moderate-to-large benefit (*d* =.64) in the neutral music condition, compared to the no-music condition.

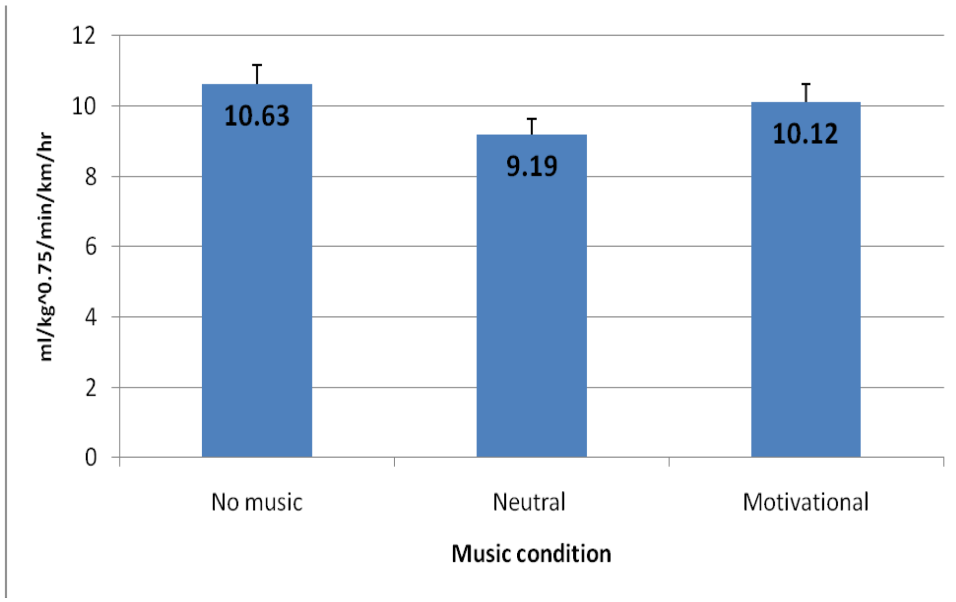

Figure 3.6. Mean Normalised Running Economy Values for Three Conditions (*n* =11)

Figure 3.7 illustrates the oxygen consumption in the three conditions across the first three time points representing the steady state treadmill running trials. After the first steady state running bout, oxygen consumption compared to no music showed a decrease of 1.3% when running to neutral music (*d* = .18) and 1% when running to motivational music (*d* = .14). After the second steady-state running bout, oxygen consumption was 1.9% lower (*d* = .26) for neutral music than no music. Finally, after the third and last steady-state running bout, oxygen consumption was 2.7% lower for neutral music compared to no music (*d* = .37) and 1% lower for motivational music (*d* = .14).

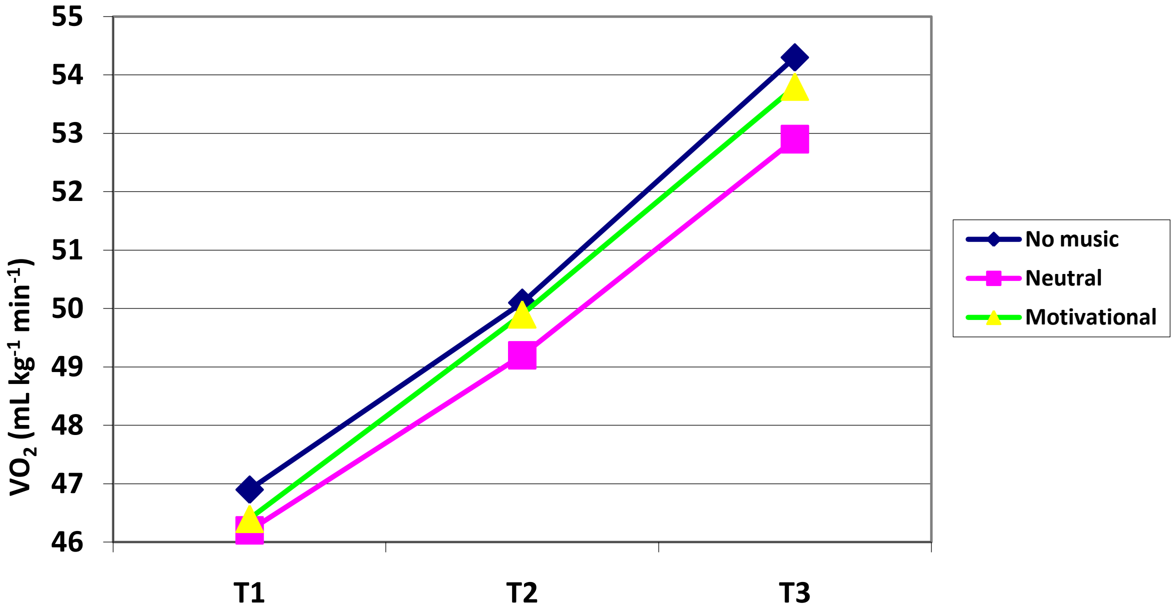

Figure 3.7. Oxygen Consumption for 11 Elite Triathletes Under Two Music Conditions and a No-music condition During Steady State Running

3.10 Discussion

The purpose of the present study was to assess psychological responses, physiological functioning and performance among elite triathletes in a laboratory running test using synchronous neutral and motivational music. Results demonstrated benefits of both music conditions over the no-music condition. In some cases, neutral music proved to be equally effective, if not more effective, than motivational music. All research hypotheses were supported.

A study by Karageorghis et al. (2009) found similar results using synchronous music during treadmill walking. Participants walked to exhaustion starting at 75% maximal heart rate reserve, in motivational and oudeterous (neutral) synchronous music conditions and a no-music control condition. Results showed that endurance performance was superior to no music in both music conditions, with motivational music yielding greater benefits in affect. In the present study, the use of synchronous music increased run-to-exhaustion times by more than a minute; a result that triathlete athletes and coaches would consider meaningful to training and performance.

Part of the reason for conducting this study was to demonstrate benefits of music to elite athletes in a laboratory task prior to conducting a follow-up study outdoors. The rationale for a follow-up study to test the benefits of synchronous music outdoors is to provide guidance to help maximise use of music in the regular training environment of endurance athletes, as most of their training and all competitions occur in a field setting. The results obtained in the present laboratory study provided evidence that synchronous music yields ergogenic, psychological and physiological benefits during high-intensity aerobic workouts among elite performers. This is the first study in which such effects have been demonstrated with elite performers, especially using exhaustive tasks.

CHAPTER 4: STUDY 2

4.1 Introduction

The purpose of Study 2 was to develop and test software to facilitate data collection in a field setting during Study 3. The data collected in the QAS laboratory in Study 1 required the use of fixed devices and stationary machinery, such as a treadmill equipped with Optojump to collect stride data, specialised equipment to collect blood lactate data, a respirometer to collect oxygen consumption data, a computer to deliver music and the visual presentation of scales to determine psychophysical responses before, during and after each trial. Collection of these data was possible because of the laboratory setting for Study 1. This would clearly not be possible in a field setting so modern technology was used to collect data outdoors, committing to ecological validity.

For the purpose of collecting relevant field data, Apple 3G *i*Phones were chosen as the most appropriate mobile device. The *i*Phones are programmable to utilise the GPS facility for distance and pace information, delivery of the BRUMS prior to commencing and after completing each run, delivering of the music, and use of audiofeedback to gather response to the scales used during the run. In short, the *i*Phone allowed us to collect data before, during and after each run.

Six *i*Phones were purchased for programming with custom-designed software required to collect the necessary data. The programme was named *Alex App* and was developed by the University of Southern Queensland’s Psychology Technology support services (USQ Psych Tech), following the researcher’s direction. The researcher explained the information collected in the first study and USQ Psych Tech then reviewed how each piece of information could be collected and programmed on the *i*Phone. The *i*Phone was programmed at various stages, verifying each stage with the researcher. For the delivery of the scales, for example, USQ Psych Tech would ask the researcher to record the verbal instructions that would be delivered during the run. The researcher recorded various lengths and deliveries of the scale and asked USQ Psych Tech to review it, as non-experts in the area. The purpose of obtaining feedback from individuals unfamiliar with RPE and the Feeling Scale was to ensure that the information delivered verbally during the run was clear and easy to answer by anyone whilst running. All other elements of *Alex App* were pilot tested, including start up and termination of data collection, and the delivery of the BRUMS. Once the *i*Phones were ready for data collection, *Alex App* was tested on two non-elite runners who ran regularly.

4.2 Participants

Participants were one Australian and one American recreational triathlete and runner, 41 and 25 years of age, respectively. Neither participant had previously been exposed to the scales or BRUMS collection, via *i*Phone or otherwise. Participants were asked to report any technical problems or annoying characteristics of *Alex App* before or during the run. Participation was voluntary with the sole purpose of testing the *i*Phone software prior to its use for data collection in Study 3.

4.3 Measures

The materials used in Study 2 were the Brunel Mood Scale, the Borg Scale (RPE), and the Feeling Scale, all of which were described in detail in Study 1, plus various music tracks, and the *i*Phone. It was unnecessary to rate the music tracks used in this study for their motivational qualities, using the Brunel Music Rating Inventory or some other method, because the purpose was not to test effects of music but rather to evaluate the performance of the *i*Phone as a means of data collection.

The intent was to anticipate any glitches that could occur during running, such as start-up and finish commands, GPS collection, music playback, audio feedback prompts, and anything else that was reported to be irksome to the runner during their regular training session. Both participants were regular runners who used the *i*Phone multiple times, providing feedback after each run. For all trials, participants rated their mood states using the BRUMS at the beginning and end of each trial. The Borg Scale and the Feeling Scale were used to assess perceived exertion and feelings during the run using an audio feedback prompt programmed into the *i*Phone. Any issues were reported back after each trial.

On separate occasions, participant ran outdoors to no music or randomly selected music. Participants carried the *i*Phone in an armband and were given a choice of whether to use *i*Phone earphones provided, or their own earphones. The microphone used was the *i*Phone's in-built microphone, which was tested to record in-task voice feedback. Participants ran for a minimum of 20 minutes to a maximum of one hour. When the participant was about to commence their run, he or she clicked on the start button and waited for the GPS and the *i*Phone command button to show the word "Start" and turn green.

The *i*Phone was programmed to prompt participants to respond to the items of the BRUMS, which were answered directly onto the phone using the *i*Phone touch-screen. When the BRUMS was completed, the participant began his/her run and the iPhone began to collect GPS data. The electronic BRUMS on the *i*Phone was formatted as closely as possible to the original paper BRUMS. On the *i*Phone, the 0-4 response scale was displayed below each mood descriptor in turn. As each response was entered, the screen refreshed with a new mood descriptor but responses categories remained the same. Once the participant completed the BRUMS, participants were ready to tap on the green "Start Run" button and go.

The *i*Phone prompted the participant with an audio-feedback version of the RPE and Feeling Scale every 10 minutes up to and including the end of the run. Immediately upon completing the designated time allocated to their run, the *i*Phone informed the participant that they had completed their run, and then prompted participants with the same electronic BRUMS completed at the start of the run. Once a participant had completed all three scales, participants pressed the *Alex App* button that appeared on their screen indicating the end of their run. All data collected was saved automatically. *Alex App* was designed so that each set of data could not be erased accidentally by the participant. Figure 4.1 illustrates the sequence of the *Alex App* in block diagram form. Visual representations of the *Alex App* were screen captured as added directions for participants in the form of the *Alex App* User Guide (see Figure 4.2).

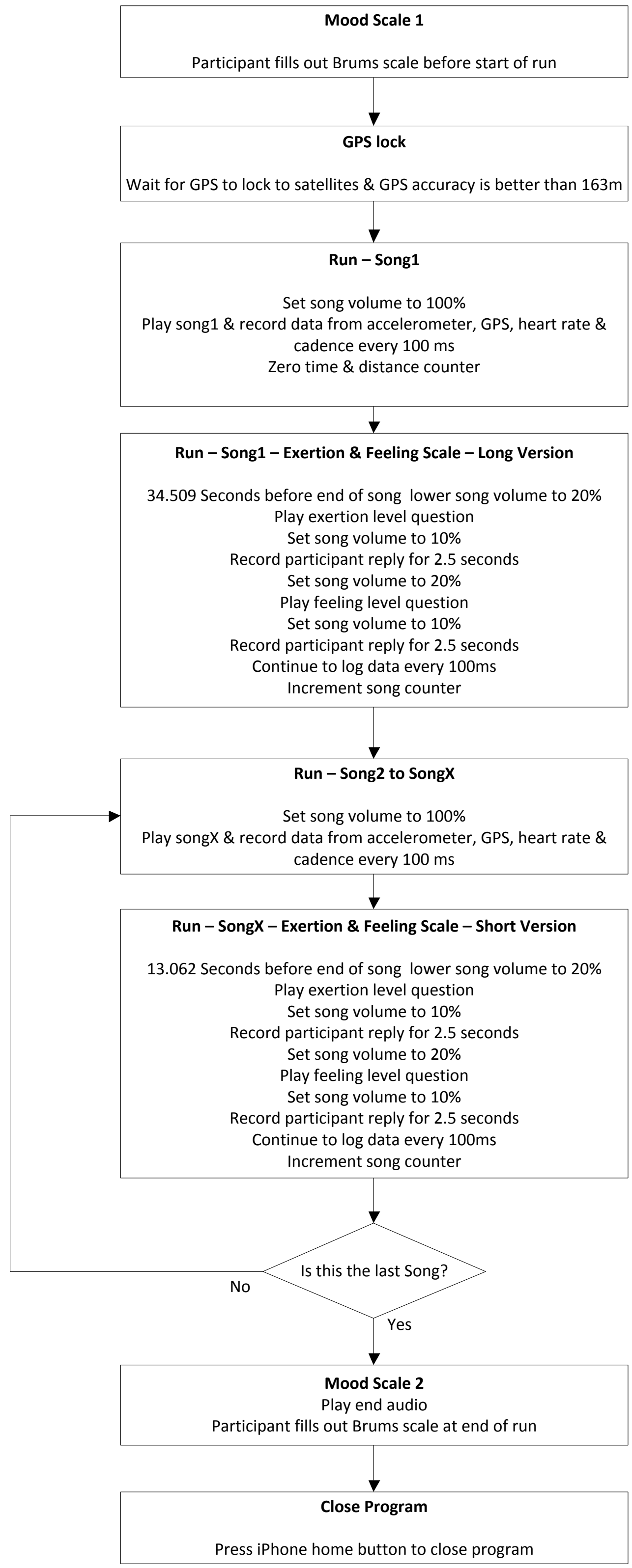

Figure 4.1. Alex App Block Diagram

AlexApp User Guide

Requirements

iPhone with AlexApp installed	
Headphones In most cases participants will use their own headphones.	
Fisica dongle	
Heart rate strap	
Footpod	
iPhone armband case	

Figure 4.2. Alex App User Guide

Guide

The iPhone should be turned off before starting.

1. Clip footpod onto shoe.
2. Place heart rate strap around chest.
3. Plug Fisica dongle into bottom of iPhone (figure 1).
4. Plug in earphones to iPhone.
5. Stand outside with a clear view to the sky. This will allow the GPS to lock onto the satellites.
6. Turn on iPhone by pressing the power button of the top of the phone. When the phone has turned on you should check if the battery is charged. In the dock there will be a number of AlexApp icons as shown in figure 2. Start with AlexApp1.2_1 for your first run. The following runs you will choose the next AlexApp above the one you have completed previously
7. Tap the AlexApp icon that you are up to. This will start AlexApp (figure 3). At the top of the screen the verion and run number is displayed. If the Fisica dongle, the heart rate strap and the footpod are operating correctly they should show as connected. The red field 1/3 of the way down the screen shows if the GPS has locked onto the satellites. Red means it is still locking onto the satellites. Once it has locked onto the staellites it will turn green.
8. Press the Start Mood Scale button at the bottom of the screen to fill out the mood scale immediately before the start of your run (figure 4). Read the question at the top of the screen and then tap on the answer that best describes how you feel. This will highlight the answer you selected and place a tick on the righthand side of the answer. If you are happy with the answer press the Next button to move on the the next question. There are 24 questions to complete.

Figure 1 – Fisica dongle plugged into iPhone

Figure 2 – AlexApp icons in dock

Figure 3 – AlexApp initial screen

Figure 4 – Mood scale

9. Once you have completed the mood scale you will return to the initial screen (figure 5). If the GPS has not already locked onto the satellites the field 1/3 of the way down the screen will still be red and the button at the bottom will display "Please Wait For Gps Lock" (figure 5). Once the GPS has locked onto the satellites the label will turn green and the button at the bottom will display "Start Run" (figure 6).

10. Place the iPhone into the armband case. Press the Start Run button. Strap the case onto the upper section of your arm. Start running and music will played through your earphones (except for the no music run). At approximatly 7 and ½ minutes you will hear a voice prompt asking you to reply with your current level of exertion and how you are feeling. Your reply is recorded by the iPhone's internal microphone, so please speak loud and clearly a number for each of these two scales. Please wait until each of voice prompts have finished before you reply. You have 2 seconds to reply after each voice prompt ends.

11. The music will continue to play (except for the no music run) and there will be a voice prompt at the end of the run (at about 15 minutes) to complete another exertion scale and feeling scale. Once you have completed the two scales you will be asked complete the same mood scale as at the start of the run.

12. Press the Start Mood Scale button (figure 3) and complete the mood scale (figure 4). Once you have completed the mood scale press the Home button on the bottom of the iPhone to exit the program (figure 8).

13. Now turn off the iPhone by pressing and holding the power button at the top of the iPhone until the slide to power off is displayed. Place the iPhone on charge for your next run.

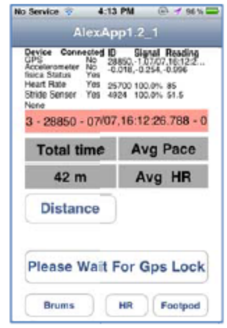

Figure 5 – Waiting for GPS lock

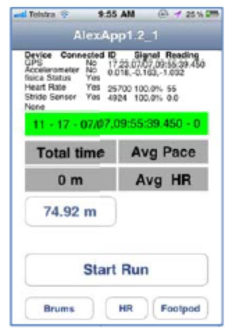

Figure 6 – Ready to start run

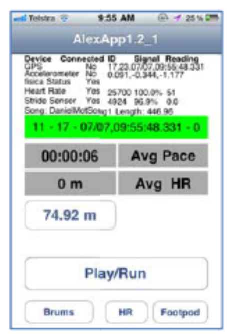

Figure 7 – Run mode

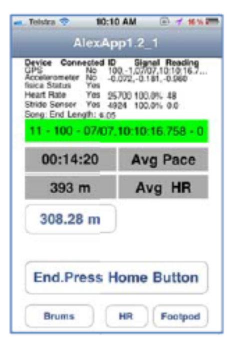

Figure 8 – Finished. Press home button

4.4 Results

Three issues were reported as a result of the running sessions. These concerned (a) the volume and length of the audio feedback required to rate RPE and the Feeling Scale, (b) the description of each scale and its numeric rating, and (c) the interference of a SIM card chip inserted into the *i*Phone. Regarding the volume and length of the voice recording delivering the RPE and Feeling Scales during each run, the volume was adjusted to factor in street noise during an outdoor run and the length for each audio feedback response was reduced from five seconds to three seconds. The five second response window was not reported as an issue during the silent condition; however, participants reported a noticeable interference in the flow when listening to music. Five seconds was considered too long to provide a response during the music conditions. Participants stated that it did not take long to become accustomed to the scales and, therefore, be able to provide a quick answer. Thus, a 3 s window was tested and successfully considered to provide sufficient time to respond without disturbing the flow of the music in the music conditions. Participants' involvement and feedback were used to make adjustments and re-test all revisions until both issues were resolved.

Regarding the description of each scale and its numeric rating, different audio promptings were recorded. It was decided that there would be two types of audio prompts: the first prompt of the RPE and Feeling Scale would include a brief description of the scale, followed by its numeric rating (e.g. "On a scale of negative five to positive five, with negative five being very bad and positive five being very good, rate how you are feeling right now."). The first prompt lasted about 13 seconds. The remaining audio-feedbacks would prompt numeric ratings only (e.g., "On a scale of negative five to positive five, rate how you are feeling right now.”). These prompts only lasted seven seconds. Participants reported a significant improvement in musical flow when reductions in the length of audio prompts were applied.

Thirdly, the *i*Phone was subject to suffer interference from any cellular phone activity during a run. USQ Psych Tech confirmed that any cell phone activity, such as an incoming phone call or SMS, would take priority over *Alex App* and interrupt the data collection. Data collected up to the interruption would not be lost but any data after that would not be stored. Therefore, the researcher determined that SIM cards should be removed before each run.

The aim of Study 2, to develop and test custom-designed software to facilitate data collection in a field setting, was achieved successfully. Having improved the functionality of *Alex App* following field testing by two participants and prior to the commencement of Study 3, meetings were held with prospective participants for a basic demonstration of the *Alex App* software. As previously clarified, written instructions were also provided with a step-by-step visual display of what *Alex App* would look like on the *i*Phone screen during testing (Figure 4.2).

CHAPTER 5: STUDY 3

5.1 Introduction

Recruiting participants for Study 3 proved challenging. Although the concept was the same and the methodology was simplified to suit a field setting, the time taken to develop, test and fine tune the software was such that it was not completed until after the start of the competition season for the group of QAS triathletes used in Study 1. This created about a 6-month gap before the same participants would be available to participate in Study 3. For this reason, the target population was revisited. However, it was necessary to ensure that results of Study 3 would still be meaningful to elite running performance. Each change to the methods originally proposed for Study 3 was discussed with all project colleagues and the QAS Centre of Excellence Director, physiologists and coaches.

The first area that was revisited was the definition of an elite athlete. It is not a straightforward task to identify the parameters of elite performance. The first objective was to define Australian elite triathletes, and therefore national websites were scrutinised to identify the pathway toward elite status. The first online resource utilized was the Triathlon Australia (TA) website. The TA site details how to get involved in triathlon. In this section, the reader is introduced to the first status boundary: age competitions versus elite competitions. Age competitions are not considered elite but they still attract committed triathletes. The reader is also told that, if successful in their age group, the triathlete may progress to participation in the elite group as well. On the TA website (http://www.triathlon.org.au/), the elite triathlete was identified as "someone who is extremely proficient at piecing together the three sports of swimming, cycling and running. They will train for many hours a week, race against the best athletes in the world and are entered into the top competitions by their National Federations. The goal of an elite triathlete is to represent their country at ITU Elite World Championships races, and ultimately achieve selection to compete at the Olympic Games." Following this, there are links to qualification criteria set by TA on how to become a high-performing elite triathlete (http://www.triathlon.org.au/Resources/High_Performance.htm) and to high performance programmes (http://www.triathlon.org.au/Elite/About_the_High_Performance_Programme.htm).

The latter link takes the reader to three national high performance programmes: the Australian Institute of Sport (AIS), the State Institute of Sport/State Academy of Sport (SIS/SAS) and the State Talent Academies (STA). All three programmes are designed to enable international success, such as indicated by participation and qualification at the Olympics and/or ITU Championships. The AIS definition of elite is someone who "competes on a state, national, or international level." QAS experts agreed that although they regarded national level participation athletes as sub-elite rather than elite, this category of athletes was still of interest for elite levels of performance, which they regarded as restricted to international participants. Therefore, for the purpose of this study, all athletes included would be considered elite by the AIS standard but may be regarded as elite or sub-elite by the QAS.

As mentioned, QAS triathlete participation from Study 1 was obstructed due to overlaps with international competitions and training, to which coaches and triathletes committed 100% of their time. In the search for additional elite triathletes in

Queensland, referrals from QAS coaches were pursued as well as elite participants being sought independently. Similar conflicts between the requirements of the research and competition scheduled were encountered. Despite the conflict in schedules, two elite triathletes were recruited.

With several months still to go before the QAS triathletes returned to Queensland from overseas competition, the QAS CoE director was approached and QAS coaches overseas contacted to gain approval for expanding the project to sub-elite and elite level *runners* rather than triathletes. This was approved and several running coaches in the Queensland area were contacted. A Toowoomba-based squad of elite junior and senior runners, known as 'Run Wild' were subsequently recruited to participate, following referral from the QAS CoE Director.

5.2. Participants

Two male triathletes and six cross country runners (5 male, 1female), who were all considered elite (two of whom held State and National titles) were recruited for participation. Triathletes were aged 26 and 23 years; cross country runners ranged from 13 to 20 years of age, with the youngest member of the team holding the 2010 National Champion title. Parental consent was obtained where appropriate, prior to participation.

5.3. Musical selections

Musical selections were made on an individualised basis, with consideration given to (a) the motivational qualities of the music, as perceived by the individual participant, and (b) whether the tempo of the music allowed it to be used synchronously with the stride rate of individual participants. Each participant emailed to the researcher an initial list of tracks that motivated them to run. Tracks were downloaded and cadence of each participant during their training run was measured in order to determine whether tracks were eligible for modification. The same criterion of ± 4 bpm used in Study 1 was applied to Study 3, meaning that a track was only modified to fit a participant's cadence if it fell within ± 4 bpm of their stride rate during a training run.

Preliminary track lists were developed for the participants' convenience, displaying names of artists, tracks and musical genre to assist their decision making. Participants rated these tracks on a 1-10 scale, with a rating of 7 or above considered as motivational. Unlike the musical differentiation between motivational and neutral music that occurred in the first study, for Study 3 it was judged unnecessary and problematic to have separate trials for motivational and neutral music. Given that the focus of Study 3 was to compare effects of synchronous music with a music-led condition and a no-music condition, and considering the problems of identifying a sufficient number of tracks at the correct tempo, the tracks used in the synchronous music condition were those rated by the individual as motivational supplemented with others of an appropriate tempo from the same or a similar musical genre.

The music-led condition also incorporated the synchronicity of the music with an extra increase in tempo in the latter stages of the run. In order to do this, each run was divided into three sections of equal duration. During the first two sections, the tempo of the music matched the participant's pace exactly, whereas during the third section, the music-led section, the tempo of the music was manipulated upwards by 2 bpm to test whether the faster music tempo would lead to a faster running pace and therefore greater distance covered. Tracks selected for the first two thirds of the run were timed accordingly to end so that a new track, with an increased tempo, could lead the change of pace in the third section of the run. This ensured that a change in tempo would not have been perceptible to the participant.

5.4 Measures

The outcome measures used in Study 3 were the BRUMS, RPE and Feeling Scale, which have already been described in detail previously. Distance travelled during each run was recorded using the GPS facility on the *i*Phone.

5.5 Procedure

The aim of Study 3 was to test effects of music in a naturalistic setting during participants' normal training runs. Although these runs inevitably varied from participant to participant, they remained constant for each individual. All participants selected a route they could complete for all three test runs. Moreover, the GPS tracking device on the iPhone mapped out each run to verify that this had occurred. In other words, each participant completed three identical training runs using synchronous music, no music, and the music-led condition.

Participants were first questioned about the duration of a regular training run for them. Most participants agreed that they had multiple training sessions, which were generally decided by their coaches. Some training sessions were shorter, intense runs, ranging from 7-12 min, while others were longer endurance runs going for 60 min or longer. Prior to commencing the study, the researcher consulted with the coaches to identify a suitable run duration that would allow all participants to complete their three trials within a two week period. All coaches and athletes agreed that a moderate duration session (15-30 mins) would be easier to fit into a two week period. Therefore, all members of the Run Wild group completed three, 30 min runs. The other two participants were triathletes who were training independently of coaches. One opted to go for the 15-min training runs whereas the other triathlete's three training runs were 70 min in duration.

The researcher met with the Run Wild group prior to participation to provide a general introduction to the study and to familiarize them with the equipment used (*i*Phone, *i*Phone armband, foot pod) and to explain the software functions, such as audiofeedback recordings, GPS recording, trial selection. Despite its popularity, only about 40% of participants were familiar with the *i*Phone. The remaining participants were instructed on how to switch it on and off, and the basic operating procedures. This basic information was essential because battery life was a potential problem for them on the day of the running trials if it was not fully charged or, even worse, if all charge had been consumed. All participants received individual demonstrations of how to use the *Alex App*. Each participant was also given a set of printed instructions with screen captures, explaining how to switch the *i*Phone on and off, which programme icon to open, what to look for, how to ensure the system was ready, how to give audiofeedback, and how to fill in the BRUMS (see Figure 4.2, as previously described). A total of six *i*Phones programmed with the *Alex App* were available for use by participants.

The two triathletes, who were the first participants to undertake testing, received detailed individual instructions and were allowed to keep the *i*Phone with them for the duration of testing. This provided them with the flexibility to reschedule their training runs where necessary. The researcher was sensitive to making the testing experience flexible so that minimal interference was imposed on their regular training runs. If a participant woke up not feeling well or if it was raining, they could postpone the testing run until conditions were "normal." In other words, we wanted the testing to align with their regular lifestyle and training, in order to simulate real life conditions as much as possible. This level of flexibility was unnecessary with the Run Wild group, who typically trained as a group under the supervision of their coach.

Participants were instructed on how to clasp their foot pod onto the shoelaces securely to ensure that it would not fall out during their run. No Sim cards belonging to participants were allowed to be inserted into the *i*Phones during running trials because phone functions, such as an incoming call, would have overridden data collection. The researcher showed each participant how to place their *i*Phone flat on the ground in an open space in order for the GPS to lock. When the GPS locked, a red tab on the screen turned green and said "Start Run". Tapping the screen over that icon began the data collection.

Following pilot testing with the Run Wild group, the potential for participants to fail to follow all designated procedures if left to their own devices became apparent, so a decision was taken that the researcher should be in attendance at all testing sessions to assist participants. A pre-test occurred for all participants to familiarise them with the equipment and procedures, and to confirm individual stride rates. The order of test conditions was determined randomly by the USQ Tech Team. Music playlists were loaded onto phones prior to each testing sessions, with overlong introductions to tracks or transitions between them edited out.

All participants in the Run Wild group completed a 30 minute run, referred to as their threshold run, under the three test conditions of synchronous music, no music and music-led. Following discussion with coaches, participants were instructed to run at a “competitive pace” during each trial, as they would during their normal training runs. It was emphasized that this was not race conditions but that it should replicate their normal training pace. All participants were reminded that they would be able to request all music used during this project as a complimentary thank you for their participation and each participant was provided with a $100 food voucher upon completion of all trials.

5.6. Hypotheses

The following research hypotheses were tested:

1. Running performance would be superior when running to music than running without music.
2. Psychological measures (mood responses and feelings) would be more positive when running to music than running without music.
3. Rate of perceived exertion would be lower when running to music than running without music.

5.7 Results

The overall results of Study 3 are shown in Table 5.1, which includes descriptive statistics and comparative effect sizes for distance run, RPE, Feeling Scale and BRUMS mood descriptors at three time points. Results are also presented graphically in Figures 5.1-5.4. A notable difference in distance covered can be observed in both the music trials compared to the no music trial (see Figure 5.1). As a group, participants ran an extra 467 m while running in time to the music compared to the no-music condition, representing a 7.5% increase in distance. Similarly, an increase in distance of 447 m was observed in the music-led condition in comparison to the no-music condition, equivalent to a 7.2% performance improvement. With respect to effect sizes, compared to no music, the music and music-led conditions both produced small-to-moderate benefits. The size of the average improved distance is judged to be a meaningful improvement for field training effectiveness.

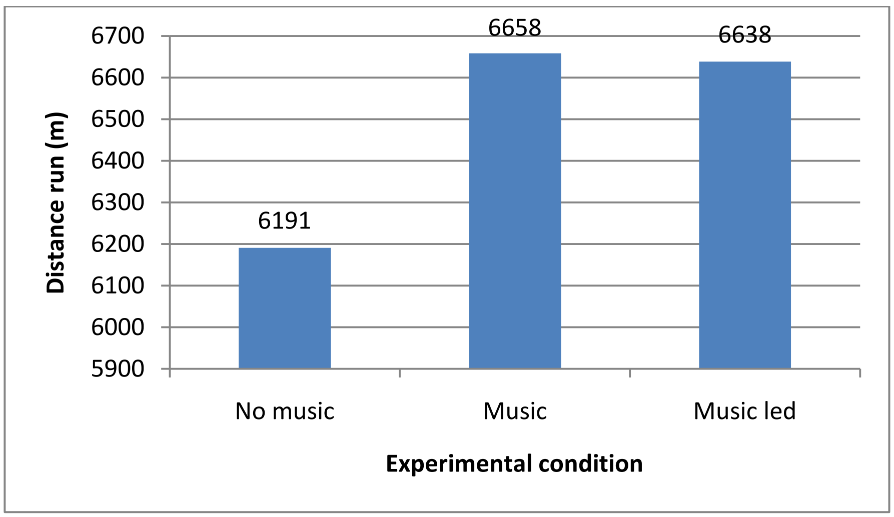

Figure 5.1. Distance for Six Junior Elite Runners and Two Elite Triathletes Under Two Music Conditions and a No-music condition.

Table 5.1

Distance Run, RPE, Feeling Scale and BRUMS Data for Six Junior Elite Runners and Two Elite Triathletes Under Two Music Conditions and a No Music Control. Data Expressed as Mean (Standard Deviation)

	Music	No Music	Music Led	Effect (*d*) Music v No Music	Music-led v No Music	Music v Music-led
Distance (m)	6658.00 (1411.25)	6191.29 (1271.89)	6637.89 (1797.98)	0.35	0.29	0.01
RPE -10 min	10.88 (2.10)	9.88 (3.04)	11.63 (1.92)	0.39	0.67	-0.38
RPE -20 min	12.00 (3.59)	14.25 (5.55)	11.88 (3.14)	-0.48	-0.52	0.04
RPE -30 min	9.63 (2.45)	13.50 (2.00)	11.50 (2.93)	-1.32	-0.76	-0.67
FS -10 min	1.75 (2.12)	1.63 (1.19)	1.38 (1.60)	0.07	-0.18	0.20
FS -20 min	0.88 (2.30)	1.00 (1.31)	1.25 (1.04)	-0.07	0.22	-0.21
FS -30 min	1.37 (1.92)	0.00 (1.10)	1.87 (0.84)	0.80	1.40	-0.34
Anger	-0.75 (4.37)	-2.13 (3.56)	-4.00 (7.35)	-0.35	0.33	-0.53
Confusion	1.50 (3.67)	0.88 (3.44)	-2.50 (7.07)	-0.18	0.60	-0.69
Depression	-0.25 (7.94)	0.25 (4.30)	-5.00 (10.20)	0.08	0.65	-0.52
Fatigue	-0.05 (10.65)	2.50 (8.55)	-3.50 (12.98)	0.27	0.54	-0.30
Tension	-1.00 (6.16)	-1.25 (2.66)	-1.50 (7.31)	-0.05	0.05	-0.08
Vigour	1.87 (11.34)	-1.50 (6.07)	4.13 (7.02)	0.38	1.32	-0.25

Note. RPE = rate of perceived exertion; FS = Feeling Scale; mood descriptor scores represent difference in T-scores from pre- to post-run for subscale of the BRUMS.

Results for perceived exertion are shown in Figure 5.2. At the 10-min mark RPE was lowest in the no-music condition but this changed quite dramatically at subsequent time points. After the second and third time point, perceived exertion was lower in both music conditions. Effects were moderate at the 20 minute mark for both music conditions, but large (music-led condition, d = -0.76) to very large (music condition, d = -1.32) at the 30 minute mark, compared to the no-music condition.

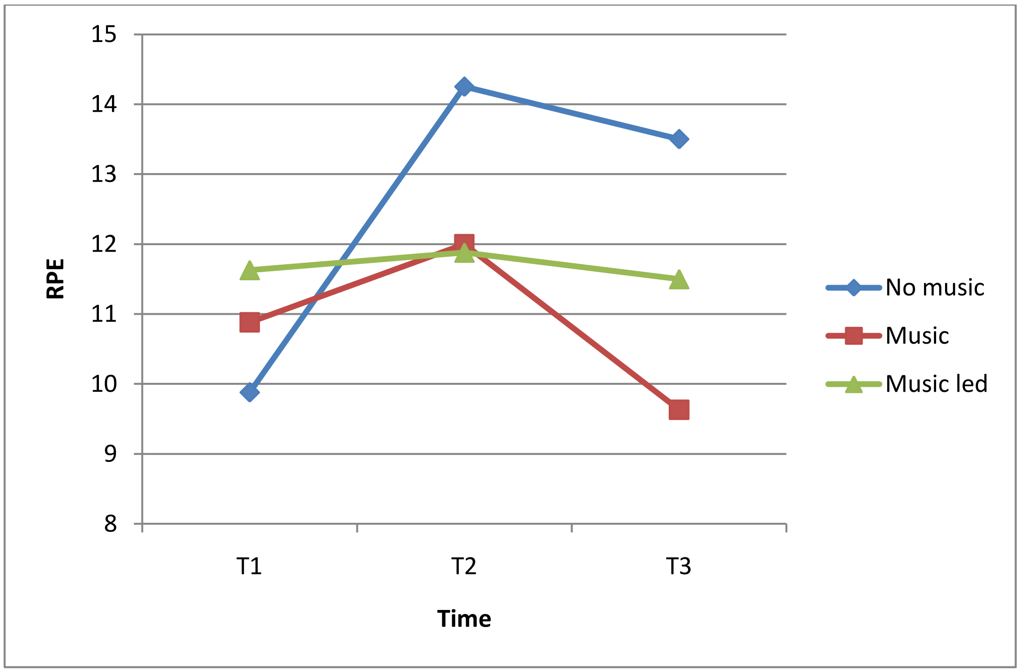

Figure 5.2. RPE for Six Junior Elite Runners and Two Elite Triathletes Under Two Music Conditions and a No-music condition

The Feeling Scale (FS) scores (Figure 5.3) show the variation in feelings during each of the running conditions. Feelings stayed positive throughout the run for all conditions. Minimal or small effects between conditions were evident at the first two time points but feelings diverged substantially at the 30 minute mark. Whereas FS scores continued to decline for the no-music condition, a rebound occurred for the two music conditions in the latter stages of the run. Effects were large for the music condition (*d* = 0.80) and very large for the music-led condition (*d* = 1.40) compared to the no-music condition.

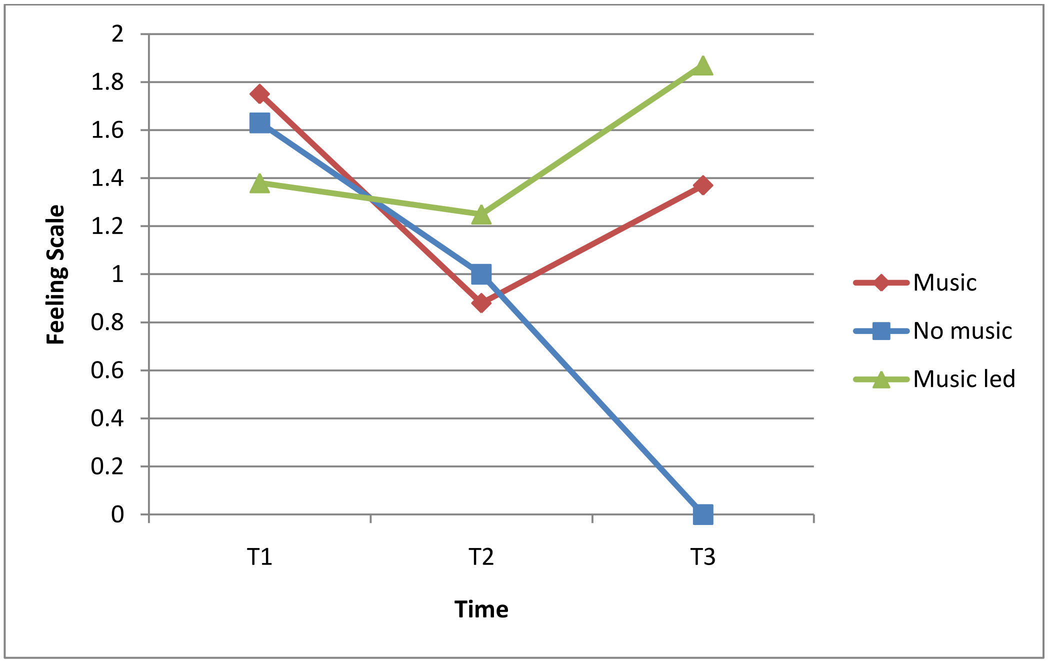

Figure 5.3. Feeling Scale for Six Junior Elite Runners and Two Elite Triathletes Under Two Music Conditions and a No-music condition

Figure 5.4 shows the changes in mood from pre- to post-run for the three conditions. The music-led condition showed the most positive mood responses by far, particularly with respect to depression, fatigue and confusion. Feelings of depressed mood rose slightly following the no music run but dropped considerably following the music-led run. A similar pattern of mood responses was observed for fatigue and confusion scores. For vigour, scores fell following the no music run but increased for the two music conditions, especially so for the music-led conditions. Tension scores dropped for all conditions approximately equally. For anger, scores dropped for all conditions but particularly for the music-led condition.

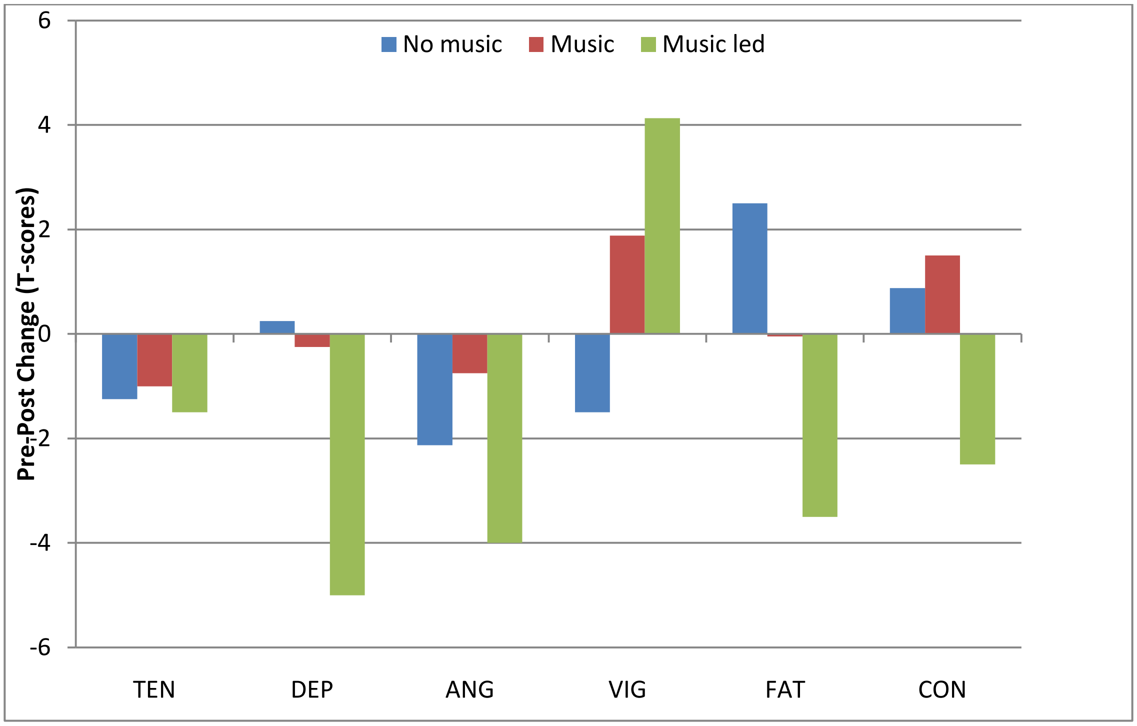

Figure 5.4. Difference in BRUMS Scores for Six Junior Elite Runners and Two Elite Triathletes Before and After Two Music Conditions and a No-music condition

5.8 Discussion

In the present research, the aim was to test the effects of synchronous music, a music-led condition and a no-music condition on affective and psychophysical responses and performance outcomes. The results add to previous literature that has previously demonstrated improved performances associated with synchronous music use (e.g., Karageorghis et al., 2011; Simpson & Karageorghis, 2006; Terry, Karageorghis, Mecozzi Saha, & D'Auria, 2012). All hypotheses were supported, given that the two music conditions showed benefits over the no-music conditions on all measured variables. Results demonstrated several benefits that elite athletes can obtain by running in time to music, with respect to perceived exertion, feeling states, mood responses and, most important to athletes and coaches, performance outcome as measured by distance covered in the same amount of time. Overall, the synchronous music condition produced the best results followed by the music-led condition, although with respect to some outcome variables the music-led condition proved superior.

Similar to the findings of Study 1, both music conditions were demonstrably better in terms of delivering the hypothesised benefits during training runs compared to training without music. As for the psychophysical and affective responses observed via RPE, the Feeling Scale and the BRUMS, all were influenced positively by the use of music. RPE particularly benefitted from the synchronous music condition while feelings and mood responses were more positive in the music-led condition. Past research had questioned whether music would benefit highly-trained participants (e.g., Brownley et al., 1995). The present results showed clearly that it does.

Hypothesis 1 conjectured that, in addition to the benefits expected from the synchronous music condition, the music-led condition would also lead to increased distance compared to the no-music condition. Based on previous research that supported the performance benefits of synchronous music, a music-led condition was introduced to test whether athletes would continue to keep pace at a higher tempo and, therefore, run even faster than with synchronous music. However, no additional benefit of being "led" by the music occurred, even though the music-led condition was clearly superior to no music. The synchronous music and music-led conditions produced almost exactly the same mean performance in terms of distance run. In the music conditions, participants may have covered more distance than without music, not because their pace increased, but because music helped them to maintain a steady pace for longer, whereas their pace likely slowed in the no-music condition.

Hypotheses 2 was supported by the data with effect sizes between the two music conditions and the no-music condition showing large-to-very large benefits of music for Feeling Scale scores at the 30 min point. Pre-post run BRUMS score changes were also more positive for both music conditions than for no music. For the music-led condition in comparison to no music, effect sizes were in the moderate to very large range for all mood dimensions except tension. Hypothesis 3 was similarly supported with large-to very large reductions in perceived exertion at the 30 min mark for both music conditions compared to the no-music condition. No hypotheses were established regarding the different effects expected between the two music conditions. However, it is apparent from the results that synchronous music was associated with the lowest perceived exertion, especially at the 30 min mark, whereas feelings and mood responses were most positive under the music-led condition.

CHAPTER 6: GENERAL DISCUSSION

The purpose of the current research programme was to assess running performance among elite athletes using synchronous music and no-music conditions in laboratory and training environments. The hypothesised outcome was that running performance and the running experience would be superior when running in time to music than running without music. This hypothesis was assessed on the basis of psychological responses, performance indices and physiological functioning. Psychological responses measured using the Feeling scale, BRUMS, and RPE scale, showed meaningful improvements during music conditions in both treadmill and training settings. Performance indices were also superior during the music conditions by meaningful margins, as measured by time-to-exhaustion in Study 1 and distance run in Study 3. Physiological measures (lactate concentration, oxygen consumption, running economy) showed small improvements in the music conditions that may be of interest to elite performers and coaches.

Several gaps in the literature were addressed by the current programme of research. Firstly, the participant population of elite athletes, in this case from both triathlon and running backgrounds, has very rarely been studied in this context. Secondly, compared to studies using asynchronous music, there has been a paucity of studies testing the effects of synchronous music. Use of synchronous music involves considerably more effort on the part of the research team but, as the present results have shown, the potential benefits are considerable. Thirdly, the present research has demonstrated music benefits in naturalistic training environments. This represents greater ecological validity than could be claimed by previous research. Fourthly, music has been shown to provide benefits even during maximal intensity exercise, which has not been demonstrated consistently in previous studies. Finally, the present programme of research used smartphone technology for delivering music and collecting data in Study 3, thereby demonstrating the potential benefits of such technology for research purposes in field settings.

The theoretical model developed by Terry and Karageorghis (2006) would indicate that the subjective experience of the athlete, shaped by a combination of situational, personal and musical factors, accounts for the observed benefits. As predicted by the model, all music conditions produced increased performances compared to trials without music, and motivational music was associated with more positive affect scores. Overall, the current results supported the reduced RPE, greater work output and enhanced psychological responses predicted by the model when music is selected appropriately. The findings of the present research programme are consistent with previous studies that have found meaningful effects of synchronous music on different areas of performance, such as psychological, psychophysical and work output. The present results may be considered to be pivotal to those seeking to apply the benefits of synchronous music with elite athletes in a training environment.

The current results are consistent with the theoretical model proposed by Rejeski (1985) whereby the shift from internal physiological cues to external stimuli depends on the elements of music, particularly rhythm. In accordance with the model, music was associated with reduced tension, anger, confusion, fatigue, and increased vigour. This finding supports and extends results reported by Hayakawa, Miki, Takada, and Tanaka (2000) and Lee (1989). Lee (1989) illustrated how music could significantly improve positive affect and reduce negative affect; Karageorghis and Deeth (2002) and Pates et al. (2003) also demonstrated that music led to an increase in flow. Similarly, other studies by Szabo et al. (1999) and Karageorghis et al. (2009) also showed that music has a positive impact on affect. The latter study by Karageorghis and colleagues (2009) made affective assessments using the same Feeling Scale (Hardy & Rejeski, 1989) that was used in the current study to measure in-task affect during an inclined treadmill walk to exhaustion. The current study supported the improved positive affect reported by participants with the use of music, particularly music that was considered motivational.

The practical implications of the current research programme are considerable. Firstly, findings provide compelling evidence that synchronous music use has a range of benefits that could be harnessed by elite athletes and their coaches. Secondly, given the benefits of music in terms of enhanced psychological responses, music use during training activities may reduce the sense of monotony that can prevail during endurance activities and thereby increase the degree of enjoyment involved in training and concomitantly reduce the potential for staleness. Thirdly, reducing perceived exertion during training activities can clearly lead to athletes completing more work for the same perceived effort, which over a sustained period can produce a greater training effect for a fixed period of training.

Perhaps most significantly in practical terms, the present research showed that music does not have to be considered motivational to provide performance benefits. By demonstrating that neutral music could yield improvements in performance *equal to or even greater* than improvements using motivational music, the current results further extended the practical application with neutral, or oudeterous, music. This result supports the theoretical observation regarding the particular importance of rhythm (Karageorghis et al., 1999; Priest & Karageorghis, 2008). It can be speculated that these results are due to the pronounced beat of the neutral music used, which often fell into the genre of R&B or rap. R&B and rap were, incidentally, considered neutral (or oudeterous) amongst all participants during both studies. Neutral music improved affect as well, although not as much as the motivational music. The performance benefits of supposedly neutral music in the present research indicates that a much broader choice of functional music may be available to athletes than was previously suggested (e.g., Terry & Karageorghis, 2006). It appears that the synchronicity of the music to the activity is more important in terms of potential performance benefits than the perceived motivational qualities of the music. The repetitive nature of synchronous music lends itself particularly well to steady-state endurance activities, such as cycling and rowing as well as running. The current results support the notion that meaningful musical benefits can be reaped in work output, physiological functioning, RPE, mood and affect even if the musical accompaniment is not considered to be motivational so long as it is synchronous. It is unknown whether this can be explained by the specific musical characteristics of the neutral music or a novelty effect, and this might provide a focus for future research investigations.

The improved work output during the trial to exhaustion in Study 1 demonstrated that music has the potential to create benefits at high intensity work-outs as well as low-to-moderate intensity exercise. This supports the view by Karageorghis and colleagues (2009) but challenges part of Rejeski's parallel processing theory (1985). The improved work output shown challenges Rejeski's theory of competing internal stimuli in higher exercise intensities, suggesting that music can be effective in providing an ergogenic effect beyond low and moderate intensities. In their study, Karageorghis et al. (2009) also point out that there may also be a difference in attentional style at play in walking versus running, such as that mentioned in different exercise modalities in 2004 by Tenenbaum and colleagues.

The current findings also support the results found by Karageorghis et al. (2009) which showed similar benefits of music on affect in running. The current findings regarding affect also support North and Hargreaves (2000), who had previously documented the preference for stimulative music during exercise activities. In other words, the motivational properties of music were aimed at enhancing their exercise response. Thus, results from the present Study 1 could have been expected to show improvements in performance as a result of improved affect. Although the latter was true, performances still yielded an overall greater result when neutral music was used. It would be plausible that the rhythm of the music would have had a greater impact on performance outcome than affect. This supports the proposed importance of rhythm in musical salience (Karageorghis & Terry, 1997).

The notion that there are appropriate balances for enhancing musical salience was put forward by Sloboda (2005) who emphasised that cognition and emotion both play a central role in determining musical benefits, such as via the dissociative effect. North and Hargreaves (2008) also found that exercisers had pre-conditioned expectations about the music that should be played based on the exercise setting (e.g., stimulative music during work-out sessions), and that such expectation can influence the effects extracted from the music. Berlyne (1971) suggested that the more arousing the stimuli, the more the potential for musical to influence responses. Stimuli with a moderate degree of arousal potential are liked most and preference decreases as the stimuli become too extreme. This could potentially explain the advantage that neutral music had to offer. Alternatively, it could be explained by a fleeting emotion to some of the lyrics or rhythms (Beedie, Terry, & Lane, 2005). In some cases, the elite athletes who participated in the first study had asked for a neutral song to be re-used in a later trial in their motivational sound track with the goal of extending their running time to exhaustion; the novelty of the music could account for such requests (Demir, Desmet & Hekkert, 2009). Karageorghis et al. (2009) also supported the benefits derived from neutral music conditions over no music conditions in a study that showed that time-to-exhaustion was increased by 6% when neutral music was used synchronously to exercise.

In the current research programme, synchronous music was associated with substantial reductions in RPE during a training run by elite participants, even though objectively they performed more work (i.e., covered more distance). It is possible that the RPE reduction was achieved because of distraction from feelings of tension and fatigue, which would support the conclusion that increasing arousal with the "right" kind of music can reduce perceived exertion. Juslin and Västfjäll (2008) had accounted for this benefit via arousal using mechanisms based on evaluative conditioning, emotional contagion, brain stem activity, visual imagery, and episodic memory as a way of stimulating emotional responses in music that is considered motivational. The elements determining the level of perceived exertion during exercise include motivation, personality, past exercise experience and direction of internal versus external focus

(Noble & Robertson, 1996). The findings of the current research would support the notion that motivation and re-direction of focus would have been at work when using synchronous music as an ergogenic aid during running. Amidst the proposed mechanisms by Juslin and Västfjäll (2008), musical expectancy states that expected beat and familiar music would lead to benefits in responses.

Study 3 used the RPE and Feeling Scale to determine in-task responses, the BRUMS to evaluate the mood state of the participant before and after each run and evaluate performance as measured by distance. Having shown a meaningful increase in distance, as well as perceived exertion, mood and feeling states, in both music conditions over the no-music condition, the overall application of the current research programme indicates that synchronous music should be considered in improving the training experience and work output. Though past research has suggested that the careful consideration of music with regard to preference, culture and familiarity be considered in the pursuit of performance enhancement, the current study found that although motivational music did increase the enjoyment of the run in indoor settings, the motivational qualities of music were not crucial to yielding meaningful improvements to times and distances in running performance. The benefits yielded in this study using musical synchronicity supports a plethora of previous findings (Bacon et al., 2008; Iwanaga, 1995a; Iwanaga, 1995b; Karageorghis et al., 2008; Karageorghis et al., 2009; Karageorghis et al., 2011; Karageorghis & Priest, 2012; Kornysheva et al., 2010; Kreitinger, 2010; Schneider, Askew, Abel, & Struder, 2010; Sridharan et al., 2007).

6.1 Limitations of the present programme of research

The main limitation of the current research was that only a small pool of elite athletes was available to participate. Three athletes who commenced participation in Study 3 were forced to withdraw. One participant withdrew following an injury and two other participants withdrew due to compulsory attendance at an extended training camp during which data collection proved impossible. Such a limitation is, of course, not unique to the present research and, in part, explains why very little research in the area of music use has been conducted with elite populations. Finding ways to access elite populations for research purposes is a perennial challenge for researchers.

Although Study 1 was conducted in a controlled laboratory environment, Study 3 was conducted in a naturalistic setting that was inherently less controlled. Even with the best intent, it was difficult for participants to ensure the consistency of each run within the designated two week period. The rationale for keeping participation within a two week window was to reduce any training effect. Given that the aim of the study was to apply music benefits to any training setting, the consistency of the time, location, duration and intensity of each training run was essential as a part of this study to fully attribute all observed benefits to the music. In Study 3, it was not possible to measure the physiological variables of performance, in terms of lactate and running economy, for technical reasons. Also, though the volume was adjusted before each trial to assure consistent delivery of the music, the situational differences were subject to variation based on the outside conditions, such as traffic noise and other music playing from cars or public events nearby. In some cases, participants had to repeat in-task responses they attempted to record, at the end of their run. In one case, the technology failed to store the

GPS/distance for one run and the participant was unavailable to repeat that run. The data set for that participant was therefore omitted.

The technology developed in Study 2 and used in Study 3 proved to require significant time to familiarise participants prior to commencing data collection. Many trials were conducted in Study 2 to identify glitches that might occur during outdoor testing but nevertheless some technical problems arose. For example, the *i*Phone required the GPS to lock onto the current location. In one case, the GPS lock stalled for more than 10 minutes, which may be considered lengthy by an athlete who is feeling energised and anxious to go. In most cases, the GPS lock required about a minute to activate. For this reason, participants were pre-advised to prepare the phone by switching it on while they were changing into their running shoes or tying their shoelaces. All participants were advised to switch their phones on outdoors as GPS lock required a clear connection to the sky (i.e., not in a building).

To overcome this potential obstacle, at least one member of the research team was present for at least one of each participant's runs. When on site, the researcher helped set up all *i*Phones prior to each participant's arrival so that the *i*Phone would be ready for completion of the BRUMS and assistance for strapping the armband around each participant's arm. Alternatively, participants running solo were instructed to switch their phones on and wait for the GPS to lock once they got to the track while they warmed up and stretched. All participants were asked to keep their SIM cards out of the *i*Phones because it interfered with data collection during a run if a call or text was received while *Alex App* was running.

Despite the range of positive benefits observed using synchronous music in this research programme, one limitation relates to the concept of meter. In music, meter is the pulse of the music. In musical scripts, it is intended to emphasise the recurring pattern of stresses and accents, suggesting how the piece is to be played. In listening terms, however, meter is subjective. How an individual perceives the pulse of the music may not correspond to the actual rhythm. Meter is not a novel concept but accounting for its effects in studies using synchronous music has rarely been addressed. It should be considered in future investigations when assessing whether participants are running synchronously to music because, if a participant believes a track to be 80 bpm, it would not matter whether the actual bpm of the song is 84 bpm. In other words, accounting for meter ensures that the synchronicity of the song is being heard accurately by the listener. Meter can be assessed using a tapping system, whereby an individual taps out what is perceived to be the tempo of a track. Assessing meter acknowledges the careful selection of music that is crucial in maximising benefits on performance, advocated by Terry and Karageorghis (2006). The current study did not assess individual perceptions of meter, such as by tapping, yet the results yielded benefits with synchronous music in both neutral and motivational conditions. The present research may have potentially yielded *greater* benefits had the issue of meter been accounted for, thus, this is acknowledged as a limitation of the present research and it is recommended for consideration in future synchronous music studies.

6.2 Recommendations for future research

The study of music in elite athletes is particularly difficult in its recruitment and appeal for athletes and coaches. Many elite coaches and dedicated athletes are concerned with the interference participation can cause in their regular training so future research programmes that have minimal interference on regular training sessions are recommended. Given the high motivation of elite populations, it would be useful to complete a reward package that is a motivator for future training and performances, such as a personalised digital soundtrack, and/or information on how to use data for performance enhancement. This has general appeal for its immediate application. Once participants have been recruited, the use of the *i*Phone in gathering data independently of the researchers' assistance makes it more likely for errors to occur. Although individuals may be familiar with the use of an *i*Phone, it is recommended that the software (or "app") used to collect data would best be advised to have a simple instruction sheet to guide the user.

It is also recommended that, prior to engaging in actual data collection, participants be thoroughly familiarised with the process by a member of the research team who is capable of assisting them with any problems and, if possible, be present on location before and immediately after their run. Instructions for audiofeedback and assessment of variables such as RPE and the Feeling Scale are best reviewed during pilot data collection prior to the study itself. The BMRI (the most recent BMRI-3 is recommended, although the BMRI-2 is also considered valid) should be incorporated in studies looking at externally valid evaluation of motivational music. It is also recommended that the music used with trained athletes be synchronously paced to the activity (Crust, 2008; Schneider, Münte, Rodriguez-Fornells, Sailer, & Altenmüller, 2010), although this involved a very large commitment of time and effort.

In working with elite athletes, synchronous music choices are limited due to the very high cadence of elite runners and triathletes. A wider range of musical options will become available by using slow tracks which halve the stride cycle. For example, an elite athlete's pace might have his or her feet landing on the ground 180 times per min. Instead of using a track of 180 bpm (very hard to find), a track whose pace is 90 bpm would equally be suitable to synchronise with stride rate, whereby the athlete runs two strides to each beat. It is also recommended that future researchers design and conduct investigations that elaborate on the benefits observed in field settings and in music-led conditions. Field settings are of particular interest to elite athletes because providing a practical application for performance enhancement of even small amounts is of major interest in a sporting world where the difference between first and second place is often determined by milliseconds. The benefits that can be obtained by increasing music tempo during trials, previously documented by Szabo et al. (1999) were also demonstrated in the present research, and are relevant to any coach or athlete who uses music in a regular training setting. The use of music-led condition showed some promising results and hence it is recommended that use of music-led conditions be considered in future investigations.

6.3 General Conclusions

Synchronous music is a powerful tool for enhancing performance and increasing the enjoyment of sport and exercise. Its application can be used successfully in elite sport settings, both indoors and outdoors, and the selection of motivational music over neutral music may not be crucial to reaping the benefits. Music was shown to elevate affective responses and decrease RPE, and therefore can be a useful tool for sport psychologists working toward increasing enjoyment and motivation. The effectiveness of its use for increasing time and distance run make synchronous music a potentially effective intervention for elite performers.

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Appendix A

Names of Track Titles, Artists, Musical Genre and BPM

Track Title	Artist	Genre	BPM
Maria Maria	Carlos Santana	Latin/Hip hop	98
Crazy	Britney Spears	Pop	100
Get Your Number	Mariah Carey feat. Jermaine Dupri	R&B	100
Your L.O.V.E.	Eve feat. Wyclef Jean	Reggae mix	94
These Words	Natasha Beddingfield	R&B/Pop	97
Kryptonite	3 Doors Down	Alternative	98
Soul To Squeeze	Red Hot Chili Peppers	Alternative	88
Independent Women	Destiny's Child	R&B	98
Irreplaceable	Beyoncé	R&B	88
2 Of Americaz Most Wanted	Snoop & Tupac	Hip hop	100
Gotta Man	Eve	R&B	90
That Girl	Pharrell Williams	R&B	96
Desperately Wanting	Better than Ezra	Alternative	100
Slow Cheetah	Red Hot Chili Peppers	Alternative	90
This Time	Janet Jackson	R&B	97
Sexy Can I	Ray J	R&B	86
Overprotected (Continued)	Britney Spears	Pop	96

(Continued) **Drop It Like It's Hot**	Snoop Dogg	R&B	92
Dreams	Gabrielle	Pop	99
Let There Be Rock	AC/DC	Rock	91
Sometimes	Britney Spears	Pop	96
Love Thy Will Be Done	Martika	Pop	92
Damn I Wish I Was Your Lover	Sophie B. Hawkins	Pop	95
People Everyday	Arrested Development	Pop	91
Sweat (A La La La La Long)	Inner Circle	Pop/Reggae	87
(I Can't Help) Falling In Love With You	UB40	Pop	86
Informer	Snow	Pop	98
Sleeping Satellite	Tasmin Archer	Pop	96
The Right Kind Of Love	Jeremy Jordan	Pop	91
Mmm Mmm Mmm Mmm	Crash Test Dummies	Pop	93
Tell Me	Groove Theory	Pop	93
Waterfalls	TLC	Pop	86
Return Of The Mack	Mark Morrison	R&B	95
You're Makin' Me High	Toni Braxton	R&B	92
I Live For You **(Continued)**	Chynna Phillips	Pop	91

(Continued)			
Crazier	Taylor Swift	Pop	89
Dilemma	Kelly Rowland/Nelly	R&B	84
Til I Collapse	Eminem	Rap	86
Alguien Soy Yo	Enrique Iglesias	Latin/Pop	83
Remember The Name	Fort Minor feat. Styles of Beyond	Hip hop	85
Smile	G-Unit	Hip hop	90
Basket Case	Green Day	Alternative	85
Run This Town	Jay-Z feat. Rihanna	Rap	85
Your Body Is Wonderland	John Mayer	Pop	94
You Rock My World	Michael Jackson	Pop	95
I Just Can't Stop Loving You	Michael Jackson	Pop	100
Invincible	Muse	Alternative	93
Wonderwall	Oasis	Alternative	87
Go Let It Out	Oasis	Alternative	84
Back And Forth	Robin S.	Dance/soul	96
Cowboy	Kid Rock	Country/Pop	83
Still Waiting	Sum 41	Alternative	96
No Brains	Sum 41	Alternative	88
Decoy	Sybreed	Heavy metal	100
Fearless	Taylow Swift	Pop	100
(Continued)			

(Continued)			
Uncle Johnny	The Killers	Alternative	87
The Taste Of Ink	The Used	Alternative	98
Crazy In Love	Beyoncé	R&B	99
Your Love Is My Love	Whitney Houston	R&B	83
More Than A Woman	Aaliyah	R&B	87
Buzzin	Shwayze	R&B	93

Appendix B

Virtual DJ software

Appendix C

Researchers and Participant in the Laboratory during Study 1 Testing

Appendix D

Brunel Music Rating Inventory – 2

USQ

PER STUDIA MENS NOVA

AUSTRALIA

Brunel Music Rating Inventory–2

(Karageorghis, Priest, Terry, Chatzisarantis, & Lane, 2006)

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 E

Brunel Mood Scale (BRUMS) (As Used in Study 1)

USQ

AUSTRALIA

Brunel Mood Scale (Terry et al., 1999,2003)

Name:___________________________ Age:________ Gender: M/F

Date:_________________ Motivational ❑ Neutral ❑ No Music ❑

Below is a list of words that describe feelings. Please read each one carefully. Then cross the box which best describes HOW YOU FEEL RIGHT NOW. Make sure you answer every question.

Please cross one box for each word.

		Not at all	A little	Moderately	Quite a bit	Extremely
1.	Panicky	❑	❑	❑	❑	❑
2.	Lively	❑	❑	❑	❑	❑
3.	Confused	❑	❑	❑	❑	❑
4.	Worn out	❑	❑	❑	❑	❑
5.	Depressed	❑	❑	❑	❑	❑
6.	Downhearted	❑	❑	❑	❑	❑
7.	Annoyed	❑	❑	❑	❑	❑
8.	Exhausted	❑	❑	❑	❑	❑
9.	Mixed-up	❑	❑	❑	❑	❑
10.	Sleepy	❑	❑	❑	❑	❑
11.	Bitter	❑	❑	❑	❑	❑
12.	Unhappy	❑	❑	❑	❑	❑
13.	Anxious	❑	❑	❑	❑	❑
14.	Worried	❑	❑	❑	❑	❑
15.	Energetic	❑	❑	❑	❑	❑
16.	Miserable	❑	❑	❑	❑	❑
17.	Muddled	❑	❑	❑	❑	❑
18.	Nervous	❑	❑	❑	❑	❑
19	Angry	❑	❑	❑	❑	❑
20.	Active	❑	❑	❑	❑	❑
21.	Tired	❑	❑	❑	❑	❑
22.	Bad tempered	❑	❑	❑	❑	❑
23.	Alert	❑	❑	❑	❑	❑
24.	Uncertain	❑	❑	❑	❑	❑

Appendix F

Feeling Scale (As Used in Study 1)

USQ

AUSTRALIA

Feeling Scale

(Hardy & Rejeski, 1989)

While participating in exercise, it is common to experience changes in mood. Some individuals find exercise pleasurable, whereas others find it to be unpleasant. Additionally, feelings may fluctuate across time. That is, one might feel good and bad a number of times during exercise. Scientists have developed this scale to measure such responses.

+5	**Very good**
+4	
+3	**Good**
+2	
+1	**Fairly good**
0	**Neutral**
-1	**Fairly bad**
-2	
-3	**Bad**
-4	
-5	**Very bad**

Appendix G

Ratings of Perceived Exertion (As Used in Study 1)

USQ

PER STUDIA MENS NOVA

AUSTRALIA

Ratings of Perceived Exertion

(RPE: Borg, 1970)

Choose a number that best describes the level of exertion you are feeling:

6	
7	**Very, very light**
8	
9	**Very light**
10	
11	**Fairly light**
12	
13	**Somewhat hard**
14	
15	**Hard**
16	
17	**Very hard**
18	
19	**Very, very hard**
20	

Appendix H

Consent Form (As Used in Study 1)

Dear Triathlete,

You are invited to participate in an investigation of the effects of music during treadmill running, which is being conducted by researchers from the University of Southern Queensland (USQ). Participants will complete four treadmill tests on separate days using the standard QAS protocol for assessing the fitness of triathletes. Blood samples and a range of physiological and psychological measures will be taken during the tests.

If you agree to take part in the study, please sign the consent form below. If you have any questions about the research, please do not hesitate to contact one of the research team or the Human Research Ethics Committee at USQ via Ashley Steele (steele@usq.edu.au). Thank you for considering being involved in this study.

Professor Peter Terry	Alessandra Mecozzi
Principal Investigator	QAS Doctoral Scholar
peter.terry@usq.edu.au	mecozzi@usq.edu.au

- I agree to have all time sheets and official race records provided to the researcher.
- I have read the information above and agree to take part in the study.
- I undertake to respond truthfully to the questions asked of me.
- I understand that my participation is voluntary and that I may withdraw at any time.
- I understand that the results of the study will be reported in a doctoral dissertation and journal articles, but that I will not be identified individually.

Name: ______________________________ Date: ____________________

Signature: ______________________________

(or signature of parent/guardian if under 18)

Appendix I

QAS Treadmill Test Record Sheet (As Used in Study 1)

Sex	Female
DOB	
Todays date	

Temperature °C

Relative Humidity %

Barometric Pressure kPa

Height cm

Mass kg

Queensland Academy of Sport
Queensland Government

Incremental Treadmill Test
Name:

Queensland Academy of Sport
Queensland Government

Age:	0.0	yrs	Height:		cm	Temp:		°C	Press:		mmHg
DOB:	0-Jan-00	d-m-y	Body Mass:		kg	Rel Hum:		%			kPa

Stage	Speed (kph)	Duration (min)	Stage Time (min)	Stride Rate (steps.min^{-1})	Heart Rate (beats.min^{-1})	Lactate (mmol.l^{-1})	RPE (6-20)	VO_2 (l.min^{-1})	RER	V_E (l.min^{-1})	Resp Rate (breaths.min^{-1})
1	14	0-1 min	1								
		1-2 min	2								
		2-3 min	3								
		3-4 min	4								
2	15	5-6 min	1								
		6-7 min	2								
		7-8 min	3								
		8-9 min	4								
3	16	10-11 min	1								
		11-12 min	2								
		12-13 min	3								
		13-14 min	4								
4	17	15-16 min	1								
		16-17 min	2								
		17-18 min	3								
		18-19 min	4								
5	18		1								
			2								
			3								
			4								
START TIME/speed Sub max ~3km											
0%			30s								
0%			30s								
0%			30s								
0%			30s								
0%			30s								
0%			30s								
0%			30s								
0%			30s								
0%			30s								
0.50%			30s								
1.00%			30s								
1.50%			30s								
2.00%			30s								
2.50%			30s								
3.00%			30s								
3.50%			30s								
					5 min post						
					10 min post						

Skinfolds (mm):	
bicep	
tricep	
subscap	
supraspinale	
abdomen	
thigh	
calf	
Total	

Appendix J

Triathlete Food Diary (As Used in Study 1)

Name: ______________ Date: __________ Day: ______________

Meal/Training	Food/Drink	Quantity	Comment
Before Training Time :			
Training			
Breakfast Time:			
Snack Time:			
Lunch Time:			
Snack Time:			
Training			
Dinner Time:			
Snack Time:			
Additional: (i.e. supplements)			

Appendix K

Four-Page Information and Consent Form Delivered Electronically for Recruitment of Participants (As Used in Study 3).

Benefits of Music for High Performance Athletes

A Research Collaboration

between the

Queensland Academy of Sport (QAS)

and the

University of Southern Queensland (USQ)

Professor Peter Terry (USQ)

Mr. Shaun D'Auria (QAS)

Mrs. Alessandra Mecozzi Saha (QAS PhD Scholar)

Dr. Costas Karageorghis (Brunel University, UK)

March 2011

Benefits of Music for High Performance Athletes

Background

Margins between success and failure in elite sport are very small, which prompts athletes and coaches to seek innovative methods to gain an edge over their competitors. At present, music interventions tend to be utilised in a random rather than a systematic fashion.

The present research project will focus specifically on exploiting this synchronisation effect in a training setting for elite triathletes. Evidence for benefits on a treadmill have already been confirmed (Terry, Karageorghis, Mecozzi Saha, D'Auria, 2012.

Aims of the Research Project

This project will evaluate the effects of music synchronised to running stride during normal training activities and will provide evidence-based guidelines for implementing music interventions into training. The main potential benefit to QAS coaches and athletes is an improvement in training effectiveness.

What's involved?

Participating athletes will use an iPhone during their regular training for a total of four sessions (one session to collect stride information and three sessions including two music conditions and one non-music condition, in random order). Participants will report their moods, perceived exertion and feelings at various points during the run. The same run (time, place, duration) will be used for all four training sessions.

The technology used to collect data during each session includes an iPhone (with earphones and armband provided), heart rate strap and foot pods to be worn during each training session.

What's in it for the participants?

Athletes who participate in the project will be thanked for their efforts in the following ways:

- Be provided with a food voucher toward their dietary intake preceding each test (valued at $50, valid at Woolworths, Caltex, Dick Smith, Dick Smith Powerhouse, Tandy, Big W, Dan Murphys and BWS);

- Be provided with an individualised report of their performance relevant to their training;
- Be provided a copy of the music used during the tests in MP3 format upon request;
- Be provided with a personalised training CD upon request;
- Be provided with a list of recommended websites supporting the use of synchronised music and instructions on how to create a synchronised playlist using your favourite tracks;
- Free consultation to provide assistance with personalised music upload following the study;
- Have the opportunity to win one of two prizes of $100.

   

<u>Reference</u>

Terry, P.C., Karageorghis, C.I., Mecozzi Saha, A., D'Auria, S. (2011). Effects of Synchronous Music on Treadmill Running among Elite Triathletes. *Journal of Science and Medicine in Sport*.

<u>How do I sign up for the study?</u>

If you are willing to participate in the study, please read and sign the consent form on the next page. Email Alex Mecozzi Saha Alessandra.MecozziSaha@usq.edu.au or send it by post to Peter Terry at USQ, Faculty of Sciences, Toowoomba, QLD 4350 (peter.terry@usq.edu.au).

Participant Information and Consent Form

Dear Elite Athlete,

You are invited to participate in an investigation of the effects of music during running, which is being conducted by researchers from the Queensland Academy of Sport (QAS) and the University of Southern Queensland (USQ). Participants will complete four running sessions on separate days using an iPhone to evaluate performance. Fitness and psychological measures will be taken during the tests.

If you agree to take part in the study, please sign the consent form below. If you have any questions about the research, please do not hesitate to contact one of the research team. Thank you for considering being involved in this study.

Professor Peter Terry	Alessandra Mecozzi Saha
Principal Investigator	QAS Doctoral Scholar
peter.terry@usq.edu.au	Alessandra.MecozziSaha@usq.edu.au

- I have read the information above and agree to take part in the study.
- I undertake to respond truthfully to the questions asked of me.
- I understand that my participation is voluntary and that I may withdraw at any time.
- I understand that the results of my tests may be shared with my coach.
- I understand that the results of the study will be reported in a doctoral dissertation and journal articles, but that I will not be identified individually.

Name: ______________________________ Date: ________________

Signature: ____________________________

(or signature of parent/guardian if under 18)

Appendix L

List of Researcher's Relevant Publications

Terry, P. C., Mecozzi Saha, A., & Bool, R. (In press). Effects of synchronous music on elite athletes during training activities [Abstract]. *Journal of Science and Medicine in Sport.*

Terry, P. C., Karageorghis, C. I., Mecozzi Saha, A., & D'Auria, S. (2012). Effects of synchronous music on treadmill running among elite triathletes. *Journal of Science and Medicine in Sport, 15,* 52-57. doi:10.1016/j.jsams.2011.06.003

Terry, P. C., Curran, M., Mecozzi Saha, A., & Bool, R. (2012). Effects of synchronous music among elite endurance athletes [Abstract]. In *Proceedings of the International Congress of Science, Education and Medicine in Sport,* Glasgow, UK, 19-24 July.

Terry, P. C., Curran, M., Karageorghis, C.I., Mecozzi Saha, A., & D'Auria, S. (2011). Chase that feeling: Recent developments in music and sport research [Abstract]. In *Turning a new page: A refreshing look at sports and exercise psychology from an Asian perspective. Proceedings of the 6th ASPASP Congress* [CD-Rom]. Taipei, Taiwan: Asian-South Pacific Association of Sport Psychology.

Terry, P.C., Karageorghis, C.I., Mecozzi, A., & D'Auria, S. (2011). Ergogenic, psychological, and psychophysiological effects of synchronous music on treadmill running [Abstract]. In Serpa, S. et al. (Eds.), *Sport and exercise psychology: Human performance, well-being and health –Proceedings of the 13th European Congress of Sport Psychology* (p. 274). Madeira, Portugal: FEPSAC.

Mecozzi, A., Terry, P.C., D'Auria, S., & Karageorghis, C.I. (2010). Effects of synchronous music on treadmill running among elite triathletes [Abstract]. In V. Mrowinski, M. Kyrios, & N. Vouderis (Eds.) *Proceedings of the 27th International Congress of*

Applied Psychology (pp. 352-353). Melbourne, VIC: Australian Psychological Society.

Terry, P.C., Lim, J., Mecozzi, A., & Karageorghis, C. I. (2009). Meta-analysis of effects of music in sport and exercise [Abstract]. In *Meeting new challenges and bridging cultural gaps in sport and exercise psychology: Proceedings of the ISSP World Congress of Sport Psychology* (p. 157). Marrakech, Morocco: International Society of Sport Psychology.

Appendix M

Research Programme Ethics Approval Letter

University of Southern Queensland

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TELEPHONE +61 7 4631 2300

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OFFICE OF RESEARCH AND HIGHER DEGREES
Ashley Steele
Ethics Officer
PHONE (07) 4631 2690 | FAX (07) 4631 2955
EMAIL steele@usq.edu.au

Thursday, 29 October 2009

Prof Peter Terry
Faculty of Sciences
USQ, Toowoomba Campus

Dear Peter,

Thankyou for submitting your project below for human ethics clearance. The Chair of the USQ Human Research Ethics Committee (HREC) recently reviewed your responses to the HREC's conditions placed upon the ethical approval for the above project. Your proposal meets the requirements of the *National Statement on Ethical Conduct in Human Research* and full ethics approval has been granted.

Project Title	Improving training effectiveness using music interventions
Approval no	H09REA095
Period of Approval	29/10/2009 – 29/10/2010
HREC Decision	**Approved**

The standard conditions of this approval are that:

(a) you conduct the project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments made to the proposal required by the HREC;
(b) you advise the HREC (email: ethics@usq.edu.au) immediately if any complaints or expressions of concern raised, or any other issue in relation to the project which may warrant review of ethics approval of the project;
(c) You make submission to the HREC for approval of any amendments, or modifications to the approved project before implementing such changes;
(d) in the event you require an extension of ethics approval for this project, please make written application in advance of the end-date of this approval;
(e) you provide the HREC with a written "Annual Progress Report" for every year of approval. The first progress report is due 12 months after the start date of this approval (by **29/10/2010**);
(f) you provide the HREC with a written "Final Report" when the project is complete;
(g) if the project is discontinued, you advise the HREC in writing of the discontinuation.

For (c) to (f) proformas are available on the USQ ethics website: http://www.usq.edu.au/research/ethicsbio/human

Please note that failure to comply with the conditions of approval and the *National Statement on Ethical Conduct in Human Research* may result in withdrawal of approval for the project.

You may now commence your project. I wish you all the best for the conduct of the project

Yours sincerely

Ashley Steele
Ethics Officer
Office of Research and Higher Degrees

Toowoomba • Springfield • Fraser Coast usq.edu.au