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On the Stability and Relevance of the Exercise Heart Rate–Music-Tempo Preference Relationship

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Abstract

Objectives: To examine the stability of the cubic (two points of inflection) exercise heart rate–music tempo preference relationship found by Karageorghis et al. (2011) in cycle ergometry using a different exercise modality (treadmill exercise). To advance previous related studies through the inclusion of psychological outcome variables (e.g., state attention and intrinsic motivation) and post-experiment interviews.

Design: A mixed-model experimental design was employed with two within-subject factors (exercise intensity and music tempo) and a between-subjects factor (gender). The experiment was supplemented by qualitative data that were analyzed using inductive content analysis.

Methods: Participants (N = 22) exercised at six intensities (40–90% HRRmax) during which they were exposed to music tracks at four tempi and a no-music control. Music preference, affective valence, and perceived activation were assessed during the task. Immediately afterwards, an attentional focus item, the short Flow State Scale-2 and items from the Intrinsic Motivation Inventory were administered. A subsample of participants (n = 8) was interviewed using a schedule of open-ended questions.

Results: Results did not support a cubic relationship but rather a quadratic one (one point of inflection), and there was a weak association between the optimal choice of music tempo and positive psychological outcomes.

Conclusions: The range of preferred tempi for treadmill exercise (123–131 bpm) was narrower than that for cycle ergometry (125–140 bpm). Regardless of its tempo, music reduced the number of associative thoughts by ~10% across all exercise intensities.

Keywords: affect, association, asynchronous music, cubic relationship, dissociation, meter

Introduction

There is a burgeoning literature on the psychophysical and ergogenic effects of music in the exercise domain (see Karageorghis & Priest, 2012a, b for a review). A key concern for researchers is to identify the musical qualities that are germane to beneficial effects across the gamut of exercise settings. Experimenters have manipulated musical qualities such as intensity (volume), style, rhythm, harmony, and lyrical content (e.g., Bishop, Karageorghis, & Kinrade, 2009; Copeland & Franks, 1991; Crust & Clough, 2006). From both research and applied perspectives, one of the easiest facets of music to manipulate is its speed or tempo as measured in beats per minute (bpm). Tempo is thought to be a key determinant of musical response (e.g., Crust, 2008; Edworthy & Waring, 2006).

Neurophysiological and psychomusicological research has shown that the rhythmical qualities of music can have a stimulative effect on humans (e.g., Khalfa, Roy, Rainville, Dalla Bella, & Peretz, 2008). Through entrainment theory (Thaut, 2008, pp. 39-59) and associated empirical investigation, we have gained a deeper understanding of how music affects the body’s main pulses such as brainwaves, heart rate, and respiratory rate (e.g., Khalfa et al.; Large, 2000). Music appears to activate neural structures in a periodic way and stimulates the limbic and reticular activating systems of the brain which are thought to govern arousal (e.g., Lyttle & Montagne, 1992).

It has been postulated that preference for different music tempi should be affected by the physiological arousal of the listener and the context in which they hear the music (e.g., Berlyne, 1971, p. 70; North & Hargreaves, 2008). Thus when an individual’s psychomotor arousal is high, it follows that they should prefer music with faster tempi. Moreover in situations that favour high arousal (e.g., during execution of highly motoric tasks), fast, stimulative music is likely to be preferred. Following two exploratory studies using musical excerpts and then entire music programmes (Karageorghis, Jones, & Low, 2006;

Karageorghis, Jones, & Stuart, 2008), Karageorghis and Terry (2009) argued that the relationship between physiological arousal and preference for music tempo may not be linear in nature. This was demonstrated in a subsequent study that used musical excerpts in four tempo categories that were played across six intensities while participants exercised on a cycle ergometer (40–90% heart rate reserve [maxHRR]; Karageorghis et al., 2011; see Fig. 1). At low exercise intensities (40–60% maxHRR) the relationship is positive and linear, and as intensity increases an *inflection point* (change of direction in the trendline) is reached at 60% maxHRR, leading to a more moderate pitch. A further inflection point occurs at approximately 80% HRRmax when the pitch of the line becomes negative; as exercise intensity increases further, the preference is for a slight reduction in tempo.

The *cubic* relationship—two points of inflection in the trendline (see Fig. 1)—that was observed in the Karageorghis et al. (2011) study can be attributed to three main factors. First, the majority of up-tempo popular music falls into a tempo band of 115–140 bpm (Karageorghis et al., 2011) and, by extension, this is also the most familiar tempo band for most westerners. Second, the dip between 80 and 90% HRRmax occurs beyond the ventilatory or lactate threshold; thus the slight attenuation in tempo preference may reflect the automatic attentional switching that takes place during high-intensity exercise, which severely limits participants' ability to focus on external stimuli such as music (Rejeski, 1985; Tenenbaum, 2001). Third, fast-tempo music tracks (> 140 bpm) may contain too much information for the limited attentional capacity of the afferent nervous system or have too great an arousal potential, irrespective of participants' heightened level of physiological arousal (Berlyne, 1971, p. 70; Rejeski, 1985).

Using a sample of tennis players, Bishop et al. (2009) investigated how changes in the tempo and intensity of music influenced affective valence and subsequent choice-reaction task performance. Their results showed that fast-tempo music elicited emotional states that were more pleasant/arousing compared to slow-tempo music, although there were no associated differences for reaction time. In a similar vein, Edworthy and Waring (2006) examined the effects of music tempo and intensity on self-selected speed of treadmill running. Fast music was associated with higher running velocities than either slow music or a white noise control. Although participants exhibited increased running velocities in the two fast-music conditions, there was no corresponding increase in perceived exertion. All four music conditions enhanced affect when compared to control with the influence of fast music being more pronounced. A limitation of this study was that music was selected only with consideration to tempo, and not other aspects that contribute to its motivational qualities, such as harmony, lyrics, and extramusical associations (Karageorghis, Terry, & Lane, 1999), which may have an impact on outcomes such as intrinsic motivation and flow (see e.g., Karageorghis et al., 2008).

One of the limitations in previous work that has examined the exercise heart rate–music tempo relationship is that the relevance of the relationship in terms of psychological outcomes has not been assessed (e.g., Karageorghis et al., 2006, 2011). Such formative studies were directed more towards establishing the nature of the relationship rather than its consequences. Extant findings indicate that optimal music selection should be associated with positive affective states, increased activation, dissociative attentional focus, and higher state motivation (Hutchinson et al., 2011; Karageorghis & Terry, 1997; Karageorghis et al., 1999). Accordingly, we do not fully comprehend the precise consequences of optimal music selection or poor selection at different exercise intensities.

Allied to the issues surrounding psychological outcomes is the potential moderator variable of gender. Past research examining complex motoric tasks (e.g., circuit-type exercises) has shown that females are likely to derive greater psychological benefits from music than their male counterparts (e.g., Karageorghis et al., 2010). However, in the case of the simple motoric task employed in the present study, gender is not expected to have a moderating influence, either on the exercise heart rate–music tempo relationship or on associated psychological outcomes (see e.g., Elliott, Carr, & Orme, 2005). Also, given that Karageorghis et al. (2011) employed a simple motoric task (cycle ergometry) it is not known whether their findings are generalizable to other such tasks (e.g., treadmill exercise). The motor patterns involved in walking/running are different to those involved in cycle ergometry, while the former is also a weight-bearing activity. This factor contributed to the rationale underlying a test the stability of the heart rate–music tempo relationship.

The purpose of the next study in this line of work is to assess the stability of the cubic exercise heart rate–music tempo relationship (see Fig. 1) using a different exercise modality to that employed by Karageorghis et al. (2011) and to examine a number of psychological outcome variables (e.g., affective valence and state attention). Thus the present study is more ambitious in scope than the preceding three studies (Karageorghis et al., 2006, 2008, 2011), meshes the best elements of those studies (e.g., a wide range of music tempi and exercise intensities), and aims to combine measurement of the relationship with an analysis of whether optimal tempo selection is associated with superior psychological outcomes. This will better enable practitioners to generalize extant findings to different exercise modalities and gauge the impact of tempo manipulations on a range of psychological outcomes (e.g., in-task affect state attentional focus, flow state).

It was hypothesized that a cubic trajectory would emerge in the exercise heart rate–music-tempo preference relationship and that this would be similar in nature to that observed by Karageorghis et al. (2011) in cycle ergometry (H_1). A secondary hypothesis was that the most positive psychological outcomes would be associated with the most appropriate tempo for each intensity (see Fig. 1). Also there would not be differences between adjacent tempi bands (e.g., medium and fast or fast and very fast) with the exception of slow vs. medium (see Karageorghis et al., 2006, 2011). Hence differences were expected to emerge between slow and medium, slow and fast, slow and very fast, and medium and very fast tempi (H_2). We included gender as an independent variable in our analyses but did not expect any gender differences to emerge (H_3).

Materials and Methods

Stage 1: Music selection

The study received ethical approval from the authors' institutional ethics committee and participants provided written informed consent. A sample of 65 volunteers who were homogenous in terms of age (M_{age} = 21.0 years, SD = 1.0, years), race (Caucasian), and education (UK secondary schools) took part in Stage 1 (see Karageorghis & Terry, 1997). The volunteers were drawn from the body of sport sciences undergraduates at a university in southeast England, UK and were asked to nominate five musical selections suitable for treadmill exercise. These nominations were for use in the experimental protocol of Stage 2. The 20 most frequently-nominated tracks were then rated according to their motivational qualities for treadmill exercise by a panel of eight undergraduate sports science students (M_{age} = 21.3 years, SD = 1.6 years) using the Brunel Music Rating Inventory-2 (Karageorghis, Priest, Terry, Chatzisarantis, & Lane, 2006). This procedure was undertaken to ensure that, although the tempi across tracks would differ, the tracks would be broadly equivalent in terms of their motivational qualities. One track was used in each of the four required tempi ranges following appropriate digital alteration of the tempi (slow, 95–100 bpm, *Buzzin'* by Mann ft. 50 Cent; medium, 115–120 bpm, *Stronger* by Kanye West; fast, 135–140 bpm, *On The Floor* by Jennifer Lopez ft. Pitbull; and very fast, 155–160 bpm, *Time* by Chase and Status).

In the present study we equated the term tempo with the closely related concept of *meter*, which concerns how the listener perceives the speed or rhythmical energy transmitted by a musical work. In popular music, there are many instances of tracks with relatively slow tempi (e.g., 80–95 bpm) that "feel" much faster to the listener due to the subdivision of beats (see Loehr & Palmer, 2009); for example tracks from the *rap* and *grime* genres. We were interested in how fast music "felt" rather than tempo per se and used a simple finger tapping exercise to extract meter and ensure that it was identical to music tempo for each track.

Stage 2: Experimental investigation

Based on a power analysis with alpha set at .05 and power at .95 (Cohen, 1988) and a moderate effect size (partial $\eta^2 = .09$; Karageorghis et al., 2006), a G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) calculation using the SPSS option indicated that 18 participants would be required. An extra four participants were recruited to protect the study against the possibility of experimental dropout and deletions due to outliers.

Participant characteristics. Twenty-two participants comprised of 11 women (M_{age} = 20.3 years, *SD* = 1.6 years) and 11 men (M_{age} = 19.6 years, *SD* = 1.6 years) were recruited from the body of sports science undergraduates at a university in southeast England, UK. These participants had not taken part in Stage 1, but did match the age profile, race, and educational background of the volunteers recruited in Stage 1. Participants were drawn from sports that have a significant requirement for aerobic energy production (e.g., outfield players from weight-bearing sports) and all reported that they did not have a hearing deficiency.

Apparatus. A treadmill (Powerjog GXC200) was used for testing along with a wall-mounted stereo system (Tascam CD-A500), and a decibel meter (AZ 8928 Sound Level Meter) to standardize music intensity at a safe level of 75 dBA (see Alessio & Hutchinson, 1991). Target heart rate was assessed by use of a heart rate monitor strapped to the chest of each participant and a sensor (Polar Accurex Plus, 1996) held by the experimenter.

Measures

***Music preference*.** At each of the six exercise intensities, music preference was assessed using a single item based on a 10-point scale anchored by 1 (*I do not like it at all*) and 10 (*I like it very much*). This item essentially tapped *music liking* using the response set "based on how you feel right now, rate how much you like this track". Music liking is used synonymously with preference in the present study (and in previous related studies; e.g., Karageorghis et al., 2011) given that *all* of the excerpts would need to be played for each intensity with each participant giving a retrospective ranking in order for researchers to establish preference in the strict sense (i.e., rank order of tracks).

In-task affect. We assessed in-task affective valence using Hardy and Rejeski's (1989) 11-point Feeling Scale which has a single-item scale ranging from +5 (*very good*) to -5 (*very bad*). The scale has demonstrated satisfactory validity across three experiments reported by its originators that reinforced its merit as an index of in-task affect.

Perceived activation. We assessed perceived activation using Svebak and Murgatroyd's (1985) Felt Arousal Scale. This is a single-item scale ranging from 1 (*low arousal*) to 6 (*high arousal*) that has been shown to have a moderate-to-strong positive correlation with the arousal scale of the Self-assessment Manikin and the arousal scale of the Affect Grid (Ekkekakis, Hall, & Petruzzello, 2008).

Attentional focus. A measure of attentional focus was taken immediately after each trial to assess state association and dissociation. A 20 cm bipolar scale with verbal anchors of "Internal focus (bodily sensations, heart rate, breathing, etc.)" and "External focus (daydreaming, external environment, etc.)" was used. Participants were required to mark the scale with an "X" to indicate their predominant focus during the exercise bout and the level of internal or external focus was ascertained through measuring the distance from the left-hand point of the scale to the "X" in centimetres. That number was multiplied by 5 to give a score out of 100 (see Tammen, 1996).

Flow state. The 9-item short version of the Flow State Scale-2 (S FSS-2; Jackson, Martin, & Eklund, 2008) was administered immediately after each condition. Items (e.g., "The way time passed seemed different from normal") are presented on a Likert scale anchored by 1 (*Strongly disagree*) and 5 (*Strongly agree*). The scale is associated with acceptable goodness-of-fit indices (Jackson et al., 2008) and scores from the scale have been shown to be internally consistent (α = .82; Martin, Tipler, Marsh, Richards, & Williams, 2006).

Intrinsic motivation. Items from two of the seven subscales of the Intrinsic Motivation Inventory (IMI; Ryan, 1982; interest-enjoyment [IE] and pressure-tension [PT]) were completed by participants immediately after each condition. Sample items include "I enjoyed doing this activity very much" (IE) and "I felt very tense while doing this activity" (PT). The items were rated on a 7-point Likert scale anchored by 1 (*Strongly disagree*) and 7 (*Strongly agree*). Scores from both IMI subscales have been shown to be internally consistent (IE α = .78; PT α = .68; McAuley, Duncan, & Tammen, 1989).

Pre-test and habituation trial. It was necessary for participants to exercise on a motorized treadmill at a constant speed of between 6 kph (walking) and 12 kph (running), and the treadmill velocity/gradient was increased in a linear manner to elicit work intensities of 40%, 50%, 60%, 70%, 80%, and 90% maxHRR. In order to establish participants' maximal heart rate, we used an age-based calculation (207 - 0.7 x age; Gellish et al., 2007). In calculating the exercise heart rate for each of the six work intensities, HRR was established by application of the Karvonen formula (Karvonen, Kentala, & Mustala, 1957). This enabled us to standardize work intensity across participants. Subsequently, each participant was habituated to the treadmill ergometry task. Each participant spent ~20 min on the treadmill ergometer during the habituation trial, during which time the experimental protocol was explained to them.

Experimental trial. Participants were exposed to 30 conditions over six visits (five conditions per visit). Each participant visited the laboratory on six occasions to complete the experimental conditions, which were administered in a partially-counterbalanced order, ensuring that the same track was not heard twice in a single visit and that the potential for order effects was minimized. On each occasion, they walked/ran at a combination of the intensities: 40%, 50%, 60%, 70%, 80%, and 90% maxHRR while being exposed to the four tempo and no-music control conditions.

At 40–50% maxHRR participants walked at 6–7 kph to achieve the desired intensity level while at 60–90% maxHRR they ran at 8–12 kph, with corresponding increases in the treadmill gradient to achieve the desired work intensity. Participants were not exposed to the same music tempo twice within a visit and were requested to follow identical patterns of activity (no other vigorous physical activity permitted) and diet prior to each testing session. Further, they were requested not to eat within 2 h prior to testing or consume caffeine within 12 h. Each participant engaged in the trial individually in the presence of a same-sex experimenter. In order to negate the influence of extraneous visual stimuli, each participant was requested to look straight ahead at a large blank screen.

Following a 5-min warm-up at a speed of 5 kph with no music, the experimenter selected the appropriate exercise intensity by adjusting the velocity of the treadmill and altering the gradient; there was a 1% gradient increase for every .5 kph increase in velocity. Participants took ~60 s to reach a steady state at the prescribed exercise intensity; subsequently, they heard and responded to four music-tempo conditions and a no-music control, each of 2-min duration. Fifteen seconds before the end of each excerpt, each participant was asked to rate their preference for the musical excerpt and administered the Feeling Scale and Felt Arousal Scale. The S FSS-2 and IMI items were administered at a desk close to the treadmill immediately after exposure to each musical track. Thereafter, a 60-s filler was used that entailed completion of the Concentration Grid (Harris & Harris, 1984, p. 189) in order to avoid any potential carry-over effect across experimental conditions. The recovery period between each short bout of exercise was ~4 min. Each participant performed a 5-min cool-down at the end of each testing session, which lasted for ~45 min.

***Post-test interview*.** In order to corroborate the experimental findings with qualitative data and incorporate the viewpoints of participants, a subsample (n = 8) with an even split of women and men was selected randomly and interviewed by the second author for a period of ~15 min. The hypothesized psychological benefits in regard to optimal music tempo exposure were expected to be corroborated, to a degree, by the interview data. These data would also serve as a form of manipulation check. A schedule of open-ended questions was used (which can be requested from the first author) that allowed each participant's perspectives to emerge. Examples of questions include "Did the music have any effects at all on how you were feeling?" and "Did you notice any changes in the music other than the fact you were listening to four different tracks and sometimes there was silence?" Follow-up questions (probes) were used to enhance the richness of the interview and to reveal the precise meaning given by each participant to their experiences during testing (see Marshall & Rossman, 2011, pp. 145–146). The interviews were recorded digitally using a smartphone (iPhone 4) and transcribed verbatim prior to analysis.

Data analysis

Numerical data were screened for univariate and multivariate outliers. Following checks to ensure that the data were suitable for parametric analysis, mixed-model 6 x 5 x 2 (Exercise Intensity x Music Tempo x Gender) MANOVA and ANOVAs were applied to all dependent variables except the tempo preference item, which was analyzed using a 6 x 4 x 2 ANOVA (Exercise Intensity x Music Tempo x Gender). Following appropriate reconfiguration of the data, significance values (p < .05) relating to linear, quadratic, cubic, and quartic relationships were examined using a oneway ANOVA. The qualitative data collected after the experimental trials were subjected to inductive content analysis (see

Marshall & Rossman, 2011, pp. 214–221). Specifically, statements were grouped together into thematic categories and then further grouped until a point of redundancy had been reached. Two researchers with experience of similar analyses in published work validated this process using the "critical friend" approach (see Marshall & Rossman, pp. 253–254).

Results

Checks for outliers indicated that there were five univariate outliers ($z > \pm 3.29$) and these were altered to be one unit larger or smaller than the next most extreme score in the distribution (Tabachnick & Fidell, 2007, p. 77). Tests of the distributional properties of the data in each cell of each analysis ($k = 612$) revealed 38 major violations ($z > \pm 3.29$; 6.2% of cells). Specifically, the preference scores demonstrated a mild negative skew, therefore we applied a reflect and square root transformation to this variable, which served to normalize it. The IMI PT variable demonstrated a mild positive skew, therefore we applied a square root transformation, which served to normalize it. Mauchly's test indicated 19 instances in which the sphericity assumption was violated therefore Greenhouse-Geisser adjustments were made to the relevant *F* tests. Collectively, the diagnostic tests indicated that the assumptions underlying a two- and threeway mixed-model MANOVA and ANOVA, and oneway ANOVA were satisfactorily met.

Interaction effects

Tempo preference. The preference higher-order interaction of Exercise Intensity x Music Tempo x Gender was nonsignificant, as were the twoway interactions of Exercise Intensity x Gender, Music Tempo x Gender, and Exercise Intensity x Music Tempo (see Table 2 and Table 1/Fig. 1 in supplementary electronic material). In relation to H_1, the Exercise Intensity x Music Tempo interaction did not yield significant ($p > .05$) quartic or cubic trends but did exhibit significant quadratic, $F(1, 504) = 4.32$, $p = .038$, and linear, $F(1, 504) = 5.46$, $p = .020$, trends.

To facilitate interpretation of the present findings we have included two visualizations: Fig. 1 (in supplementary electronic material) depicts mean tempo-preference ratings across exercise intensities and Fig. 2 illustrates the mean and standard error of participants' most preferred tempo at each exercise intensity. Although an imperfect representation of music tempo preference, Fig. 2 enables a better depiction of the exercise HR–music tempo preference relationship and facilitates direct comparison with the Karageorghis et al. (2011) data that were captured using a broadly comparable cycle ergometer protocol (see Fig. 1).

In-task affect. The in-task affective responses (Feeling Scale and Felt Arousal Scale) higher-order interaction of Exercise Intensity x Music Tempo x Gender was nonsignificant, as was the twoway interaction of Exercise Intensity x Gender (see Table 2). In relation to (H_2), the Exercise Intensity x Music Tempo interaction was also nonsignificant (see Table 2). In relation to H_3, there was a significant twoway interaction of Music Tempo x Gender, which was associated with a moderate effect. Step-down *F* tests indicated a significant interaction for affective valence, $F(4, 1) = 2.66$, $p = .038$, $\eta_p^2 = .12$, and perceived activation, $F(4, 1) = 4.49$, $p = .003$, $\eta_p^2 = .18$. An inspection of means and standard errors indicated that affective valence scores for male participants were significantly ($p < .05$) lower under the no-music control when compared against medium, fast, and very fast tempi, and lower for slow-tempo when compared against medium-tempo music. Scores for female participants were significantly ($p < .05$) lower for no-music control when compared against all experimental conditions, and lower when slow tempi were compared against medium tempi. A similar examination for perceived activation showed that scores for male participants were significantly ($p < .05$) lower for the no-music control when compared against slow, medium, and fast tempi. Scores for female participants were significantly ($p < .05$) lower in the no-music control when compared against all experimental conditions. Scores were also significantly (p < .05) lower in the slow-tempo condition when compared to the medium- and fast-tempo conditions.

State attention. The state attention higher-order interaction of Exercise Intensity x Music Tempo x Gender was nonsignificant, as were the twoway interactions of Exercise Intensity x Gender, and Music Tempo x Gender (see Table 2). In relation to H_2, the Exercise Intensity x Music Tempo interaction was also nonsignificant (see Table 2).

Motivation variables. The higher-order interaction for post-task motivation variables (S FSS-2, IMI IE, and IMI PT) of Exercise Intensity x Music Tempo x Gender was nonsignificant, as was the twoway interaction of Exercise Intensity x Gender (see Table 2). In relation to H_2, the Exercise Intensity x Music Tempo interaction was also nonsignficant (see Table 2). In relation to H_3, there was a significant twoway interaction of Music Tempo x Gender associated with a moderate-to-large effect size (see Table 2). Step-down F tests indicated a significant interaction for IMI IE, $F(4, 1) = 9.15$, $p < .001$, $\eta_p^2 = .31$, and flow, $F(4, 1) = 5.38$ $p = .001$, $\eta_p^2 = .21$. An examination of means and standard errors indicated that IMI IE scores for male participants were significantly (p < .05) lower for the no-music control when compared to the medium-tempo condition. Scores for female participants were significantly (p < .05) lower in the no-music control when compared against all experimental conditions, lower for slow vs. medium, and for slow vs. fast tempi. A similar examination for flow showed that scores for male participants were significantly (p < .05) lower in the no-music control compared to medium and fast tempi, lower for slow-tempo music compared to medium-tempo music, and lower for slow- and fast- tempo music (p < .05). Scores for female participants were significantly (p < .05) lower for the no-music control when compared to the experimental conditions.

Main effects

Tempo preference. The main effects revealed significant differences according to exercise intensity for preference, with pairwise comparisons indicating that the 40, 50, 60, 70% maxHRR intensities all yielded significantly ($p < .05$) higher scores when compared to 90% maxHRR, and the 50, 60, 70% maxHRR intensities all yielded significantly ($p < .05$) higher scores when compared to 80% maxHRR. There was also a main effect of music tempo for preference, with pairwise comparisons indicating significantly ($p < .05$) lower scores for slow tempi when compared to medium- and fast-tempo conditions (see Table 2). Medium-tempo scores were significantly ($p < .05$) higher when compared to very fast-tempo music, as were scores for fast-tempo when compared to very fast-tempo music. In relation to H_3, there was a main effect of gender, indicating that women had higher preference scores than men. Each of the main effects for preference was associated with a large effect size (see Table 2).

In-task affect. The main effects revealed significant differences according to exercise intensity for affective valence and perceived activation (see Table 2). Step-down *F* tests exhibited significant differences for both variables that were associated with large effect sizes: affective valence, $F(2.29, 45.77) = 20.77$, $p < .001$, $\eta_p^2 = .51$, and perceived activation, $F(2.32, 46.35) = 25.49$, $p < .001$, $\eta_p^2 = .56$. Pairwise comparisons for affective valence indicated significantly ($p < .001$) higher scores for the 40, 50, 60, 70, and 80% maxHRR intensities when compared with 90% maxHRR, and scores for the 40, 50, 60, 70% maxHRR intensities were significantly ($p < .05$) higher compared with 80% maxHRR. There was also a main effect of music tempo for affective valence and perceived activation (see Table 2), with step-down *F* tests indicating that both variables exhibited significant differences that were associated with large effect sizes: affect valence, $F(2.88, 57.57) = 24.62$, $p < .001$, $\eta_p^2 = .55$ and perceived activation, $F(4, 80) = 20.87$, $p < .001$, $\eta_p^2 = .51$.

Pairwise comparisons indicated significantly ($p < .001$) lower affective valence scores during the no-music control when compared to the experimental conditions. There were also significantly ($p < .05$) higher scores with the medium-tempo condition when compared to the other three tempi. Pairwise comparisons for perceived activation indicated that the no-music control was significantly ($p < .001$) less arousing than the four experimental conditions. In addition, there were significantly ($p < .05$) higher scores with medium tempo when compared to slow tempo, and between medium and very fast tempi. Moreover, scores were significantly ($p = .039$) higher in response to fast-tempo music when compared to very fast-tempo music.

*State attention***.** The main effects revealed significant differences according to exercise intensity for state attention that were associated with a large effect (see Table 2). Pairwise comparisons indicated that all exercise intensities differed from each other significantly ($p < .05$) with greater amounts of associative thoughts at each subsequent exercise intensity from 40% maxHRR through to 90% maxHRR. There was also a main effect of music tempo for state attention, with pairwise comparisons indicating significantly ($p < .05$) greater amounts of associative thoughts during the no-music control when compared against the experimental conditions.

Motivation variables. The main effects revealed significant differences according to exercise intensity for the motivation variables associated with a large effect (see Table 2). Step-down F tests indicated that only IMI PT exhibited significant differences, $F(2.55, 51.01) = 37.50$, $p < .001$, $\eta_p^2 = .65$. Pairwise comparisons showed that IMI PT scores at 40% maxHRR intensity were significantly ($p < .05$) lower than all other intensities, as were scores at 50% maxHRR when compared against the intensities from 60 to 90% maxHRR. Also, IMI PT scores were significantly ($p < .05$) lower at 60% maxHRR when compared to both 80 and 90% maxHRR, between 70% maxHRR and both 80 and 90% maxHRR, and between 80 and 90% maxHRR. There was also a main effect of music tempo for the motivation variables associated with a large effect (see Table 2). Step-down *F* tests indicated that all three motivation variables exhibited significant differences, flow: $F(1.82, 36.41) = 7.78$, $p = .002$, $\eta_p^2 = .28$, IE: $F(2.40, 47.97) = 28.34$, $p < .001$, $\eta_p^2 = .59$, and PT: $F(2.77, 55.46) = 5.77$, $p = .002$, $\eta_p^2 = .22$.

Pairwise comparisons for flow indicated significantly ($p < .05$) lower scores with the no-music control when compared to the four experimental conditions. There were also significantly ($p < .05$) lower scores with slow tempo when compared with both medium and fast tempi, and between fast-tempo and very fast-tempo music. Pairwise comparisons for IE indicated significantly ($p < .001$) lower scores with the no-music control when compared against the experimental conditions. There were also significantly ($p < .05$) lower scores with slow-tempo music when compared with both medium and fast tempi, and fast-tempo music led to significantly ($p < .05$) higher scores when compared with very fast-tempo music. Pairwise comparisons for PT showed significantly ($p < .05$) higher scores with the no-music control condition when compared to the four experimental conditions.

Inductive content analysis

We conducted interviews with a subsample of eight participants and the subsequent inductive content analysis of their responses is included as a supplement to the quantitative analyses. Participants indicated that the use of music per se (regardless of tempo) elicited a broad category of response that we have labeled “Enhanced exercise experience” (see Table 3). Examining this general dimension in greater depth, the raw data themes revealed benefits that reflected the three main outcomes contained in Karageorghis et al.’s (1999) conceptual framework of positive mood state, increased arousal, and dissociation (first-order themes). Participant 10 highlighted how “At higher intensities the music had more of an effect on me – it made me feel better.” Similarly, in relation to arousal, participant 25 stated “So it really made me, like ….up for it.” Seven participants passed comment on the dissociative effects of music; typical of these was the following "The music gives you something to concentrate on other than pain." (participant 10).

A second category emerged labelled "Behavioural responses to music" (see Table 3), which embraces raw data themes pertaining to perceived increases in motivation with and entrainment to music. In relation to the former, participant 16 revealed "There were a couple of songs that stood out, that kind of made me push it more." In regard to the latter, participant 1 explained "I don't think I was trying to keep in time with the music, I think it just sort of ended up going that way." Participant 13 commented "I think I changed my steps to the beat of the music, because it was easier to run along to it." Moreover, the tempo of the music was relevant to some of the participants with reference to exercise intensity; participant 1 revealed "My preference for the JLo track depended on how quick I was going."

Discussion

The main purpose of the present study was to assess the stability of a cubic exercise heart rate–music tempo relationship using a different exercise modality to that employed by Karageorghis et al. (2011), while the secondary purpose was to examine a number of psychological outcome variables with reference to this relationship. This secondary purpose represented the most novel aspect of the present study. A comparison of Fig. 2, which illustrates the present results for tempo preference, with Fig. 1 (from Karageorghis et al.) shows that the exercise heart rate–music tempo preference is not stable across exercise modalities, therefore H_1 is not supported. The standard errors bars in Fig. 2 also reveal greater variability in music tempo preference at the low-to-moderate exercise intensities when compared to the standard errors in Fig. 1.

The most striking difference between the two figures is that the cubic relationship found by Karageorghis et al. (2011) with cycle ergometer exercise is not evident with treadmill exercise. The present relationship suggests no discernible differences in preference among music tempi at low-to-moderate exercise intensities (40–60% maxHRR), a rise of ~4 bpm from 60–70% maxHRR, a leveling out in tempo preference from 70–80% maxHRR, followed by a sharp rise of ~5 bpm from 80-90% maxHRR. Where there is some similarity between the two studies is that the range of tempi that are preferred across a broad spectrum of exercise intensities is narrow, albeit considerably narrower in treadmill running (123–131 bpm) than in cycle ergometry (125–140 bpm).

Present findings pertaining to the preference for medium–tempo music across all intensities bear resemblance to those of Karageorghis, Jones et al. (2006) and Karageorghis et al. (2008) who showed that participants engaged in a treadmill walking task reported similar scores for medium-tempo music at low-to-moderate intensities with a slight dip in preference in the high-intensity condition (75% maxHRR). Fig. 1 (in supplementary electronic material) illustrates how the only meaningful differences in preference were between medium-tempo music and the remaining tempo conditions at 40–50% maxHRR, between both medium- and fast-tempo conditions compared with the remaining conditions at 60–80% maxHRR, and between slow tempo and medium, fast, and very fast tempi at 90% maxHRR. At running intensities of 40–80% maxHRR, it appears that music in the very narrow tempo range of 123–127 bpm is optimal (see Fig. 2). A further similarity with the 2006 paper concerns the Exercise Intensity x Music Tempo interaction which yielded identical effect sizes, of a moderate order, in both studies ($\eta_p^2 = .09$).

Psychological Outcomes

The present study extended previous work (e.g., Karageorghis et al., 2008, 2011) through the inclusion of a range of psychological outcomes to gauge whether optimizing the music tempo selection was associated with superior outcomes. When we examine the present music preference findings in light of the range of psychological outcome measures, it is evident that, at the highest exercise intensity (90% maxHRR), very fast music elicited the most positive affective responses, whereas at the low intensities, the medium-tempo music had a similar effect (see Table 1). There was no discernible trend for perceived activation or flow state, although for state attention it transpired that fast- and very fast-tempo music elicited the lowest levels of association at 90% maxHRR. For the two IMI subscales, it was evident that IE was highest when medium-tempo music was played at intensities 60–80% HRRmax, whereas PT increased as intensity increased, but was not influenced by manipulations of music tempo; it was higher in the no-music control when compared to all music conditions. The IE finding mirrors that of Karageorghis et al. (2008), although they used a singular exercise intensity of 70% maxHRR and administered music programmes comprised of varying tempi. Collectively, the results show that the modest differences in music tempo preference across exercise intensities were not strongly associated with psychological outcomes when there was a match between intensity and music tempo; accordingly, H_2 was also not accepted.

The main effect of intensity on state attention results lends support to extant findings regarding an attentional shift towards associative focus as exercise intensity increases that is accompanied by a shift towards more negative feeling states (e.g., Hutchinson, & Tenenbaum, 2007; Lind, Welch, & Ekkekakis, 2009). It is evident that affective valence during the music conditions, and in particular the fast-tempo condition, is more positive than in the no-music condition (see Table 1). This finding bears similarity to those of previous experimental studies into the psychological effects of music (e.g., Edworthy & Waring, 2006; Elliott et al., 2005; Hutchinson et al., 2011; Karageorghis et al., 2008).

Gender differences were not expected to emerge; nonetheless, the results revealed a series of significant Music Tempo x Gender interactions among the psychological outcome measures that led us not to accept H_3. Women appeared to derive greater benefit in terms of affective valence when compared to their male counterparts, as their scores were higher in response to each music tempo condition relative to control. Males only appeared to benefit from the medium, fast, and very fast music tempi relative to control. Women also reported higher perceived activation in response to all tempo conditions when compared to control, whereas males reported higher perceived activation in response to slow, medium, and fast conditions only. The benefits in affective valence derived by women in response to musical accompaniment in the present study are somewhat similar to those reported by Karageorghis et al. (2010) in a synchronous circuit training task.

With reference to the motivation variables, women reported higher flow state and IE scores than men across all music tempo conditions. The implication is that women are likely to experience a more positive motivational state when exposed to music of any tempo. Allied to this, it was apparent that women reported greater preference overall for music (M = 7.05) when compared to men (M = 6.00), and this difference was of a greater magnitude than that found by Karageorghis et al. (2011; women M = 7.14 vs. men M = 6.67). Nonetheless, it should be noted that in both studies the difference in preference between genders did not reach statistical significance (p > .05).

Present Findings vs. Past Findings

The Karageorghis et al. (2011) study was the first to test the preferences for music tempo across a full range of exercise intensities. The cubic relationship that emerged warranted further investigation to establish its validity and factors such as choice of exercise modality, use of different musical selections, and the influence of the age of the participants were unknown. Thus the 2011 results should be taken to be both preliminarily and tentative in nature. One notable aspect of the 2011 findings was the narrow range of preferred tempi across a range of exercise intensities and this observation was underlined by the present findings. It appears that the range of preferred tempi for asynchronous music in treadmill exercise is only 123–131 bpm, whereas in cycle ergometry it was 125–140 bpm. There are a number of factors that might account for this disparity and these will be expounded with reference to extant theory and empirical findings.

The most prominent difference in methodological terms between the present study and the Karageorghis et al. (2011) study was the choice of exercise modality; the 2011 study selected a nonweight-bearing activity (cycle ergometry) while in the present study we used a weight-bearing activity (treadmill exercise). Although both are repetitive and relatively simple motoric tasks, the kinetic pattern, breathing patterns, and neuromuscular demands vary considerably. Also, fatigue perception is far more localized in cycle ergometry (to the quadriceps) than it is in running (whole body; see Koivula & Hassmen, 1998). Despite the fact that in both studies music was applied asynchronously, entrainment theory details the propensity of bodily pulses such as respiration rate and motor patterns to entrain to musical rhythms without conscious effort (Thaut, 2008, pp. 39–59). This was reflected in the interview data which revealed that even though participants were not consciously attempting to entrain their stride rate to the rhythmical qualities of the music, they often found themselves doing so (see Table 3). As an illustration of this, participant 1 revealed that "…if there's a song playing that I like, I like to run to the rhythm."

In the Karageorghis et al. (2011) study, pedal cadence was maintained at 75 rpm and the cycling intensity was augmented via the addition of weights that increased pedal resistance. In the present study, running intensity was augmented through a combination of increases in treadmill belt velocity and gradient. Thus there was greater variability in movement cadence in the present study. Owing to differences in height among participants, there was also greater between-subject variability in cadence. In terms of motor patterns, cycle ergometry affords fewer degrees of freedom than treadmill running.

Although the salience of music tempo has been repeatedly demonstrated (e.g., Crust, 2008, Edworthy & Waring, 2006), there are, of course, other facets of music that influence response. Chief amongst these are the mode of the music (e.g., major vs. minor; van der Zwaag, 2011), the lyrical content (Bishop, Karageorghis, & Loizou, 2007), and the subdivisions of the beat (Loehr & Palmer, 2009). We did not strictly control for the mode or harmonic content of the music other than via the BMRI-2 ratings, or how the subdivisions of the beat were interpreted. Moreover, all tracks had lyrical content and there were some differences in how participants responded to the lyrical content of the music that became apparent through the qualitative analysis. For example, participant 16 indicated at the lower exercise intensities, he found it easier to mentally process the lyrical content of the music: "…with the songs playing, I was concentrating on some of the lyrics and things, so I was processing that information."

During the postexperiment interviews, four out of the eight participants stated that they found the lyrical affirmation in Kanye West's *Stronger* (medium-tempo track) to be particularly powerful ("work it harder, make it better, do it faster, makes us stronger"). For instance, participant 5 commented "…it keeps saying 'Stronger', so you just push yourself." When tempo preference was examined independently of exercise intensity, the track *Stronger* yielded the highest score (M = 7.26) and differed significantly ($p < .05$) from both slow and very fast-tempo music. It also transpired that some participants were unable to correctly place the experimental tracks in order of tempo. Specifically, four of the eight participants in the interviews did not accurately identify the very fast-tempo track as the fastest piece of music.

Similar to the findings reported by Karageorghis, Jones et al. (2006) and Karageorghis et al. (2008, 2011), at the low intensities (40–50% maxHRR) the medium-tempo track was preferred. Fig. 3 demonstrates that there is greater scope for attention to be shifted voluntarily during low-to-moderate intensity exercise; therefore it would have been somewhat easier for participants to process the lyrical content of the music (cf. Rejeski, 1985; Tenenbaum, 2001). At the higher intensities, fast-tempo and medium-tempo music is equally preferred (see Fig. 1

in supplementary electronic material), whereas at the low intensities, medium-tempo music is preferred. These present results broadly support Berlyne's (1971, p. 70) theoretical proposition and empirical findings (see North & Hargreaves, 2008 for a review) showing that high arousal states should be associated with preferences for fast-tempo music.

Participants appear to require more stimulation through the music at moderate-to-high exercise intensities, and in particular at 90% maxHRR (Fig. 2). Nonetheless, a strong finding that emerged is that music per se (i.e., regardless of its tempo) is less preferred at 80–90% maxHRR when compared to low-to-moderate intensities (see Table 1 in supplementary electronic material) while the ratings for affective valence and associated pattern of differences across exercise intensities matched those for preference almost precisely. Although the trend for affective valence did not reach significance, the medium-, fast-, and very fast-tempo conditions ameliorated the decline in affect that is evident in the no-music condition (see Table 1).

Past work has shown that affective states are more negatively valenced when participants exercise beyond ventilatory threshold (Ekkekakis & Acevedo, 2006), and the present findings suggest that at moderate-to-high intensities, appropriately-selected music can attenuate such negative feelings. Moreover, the state attention data show a difference in the point at which the switch from a predominantly dissociative focus to a predominantly associative focus occurs with music (see Fig. 3); this switch is evident at ~68% maxHRR in the no-music control whereas it occurs at ~78% maxHRR during the fast-tempo condition. This finding is notable insofar as it demonstrates that appropriately-selected music can extend the range of exercise intensities over which dissociative thoughts take place.

Limitations of the present study

Participants' responses to music may have been influenced by factors outside of experimental control. For example, independent of tempo/meter, the beat was stronger or more clearly discernible in the slow-, medium-, and fast-tempo conditions. It is very challenging to find music in the very fast-tempo category that is equivalent in terms of strength of beat, idiom, and familiarity relative to other tempo categories. It has been argued recently that there is a biological premise for the fact that most music is composed/recorded close to a tempo of 120 bpm (Schneider, Askew, Abel, & Strūder, 2010). This tempo is allied to a "natural" walking step frequency of 2 Hz and corresponds with the notion of "natural rhythmicity"; for example the preferred spontaneous tempo of finger tapping.

A related issue concerns the lyrical content of the tracks used, which could have been interpreted differently by participants (as suggested by the qualitative data), despite the fact that the tempo and motivational qualities of the music were standardized. Thus a potential limitation is that participants' preference scores may have been influenced by the lyrical content of music (c.f. Crust, 2008). One way by which to overcome this limitation is to use a single track and to digitally alter the tempo in order to create the required experimental conditions (e.g., Bishop et al., 2009). Nonetheless, this approach can lead to a further set of limitations insofar as participants are either irritated by repeated exposure to the same track or if it is an already familiar track, engenders a negative response when it is played at non-familiar tempi.

We assessed the influence of music in a visually-sterile environment which does not represent how it is used in vivo. Moreover, given that our participants were physically active undergraduate students, the results cannot necessarily be generalized to the wider population. The inherent problem with replicating the present study with other groups is that unfit/sedentary and older participants might struggle to exercise at the high intensities required to address the research question. The "perfect experiment" is simply not attainable in this domain of scientific endeavour given that when researchers strive to release some of the controls, such as through using participant-selected music or conducting the study with gym users, internal validity is immediately compromised.

Practical implications

Although the suite of recent studies has not established a clear exercise heart rate–music tempo preference relationship, we do know that the range of preferred tempi in bipedal activities (cycling and walking/running) is much narrower than previously thought (see e.g., Karageorghis & Terry, 2009). In order to optimize tempo selections across a range of exercise intensities, selections in the range 123–140 bpm should be considered. Nonetheless, the present findings show only a weak association between preferred tempo across six exercise intensities and a broad range of psychological outcomes (see Exercise Intensity x Music Tempo effect sizes in Table 2). This means that as long as a piece of music is perceived by an exerciser to be motivational, it is likely to have a positive influence on psychological outcomes. Practitioners should, however, avoid using slow selections (< 100 bpm) for high-intensity activity or very fast selections (> 140 bpm) for low-intensity activity. The weak associations evident in Table 2 along with the means in Table 1 suggest that incongruence between exercise intensity and music tempo would not optimize psychological outcomes.

The findings reinforce the notion that, at the very highest exercise intensities (i.e., 80–90% maxHRR), there is the least potential in absolute terms for participants to derive psychological benefits from music of any tempo (Karageorghis et al., 2011; Rejeski, 1985; Tenenbaum, 2001). However, the relative benefits of music vs. no-music conditions at these highest intensities are notable from an applied perspective; for example, at 90% maxHRR there is a mean difference of 1.45 in affective valence scores between the very fast music and no-music conditions (see Table 1). What is striking from a public health perspective is that at the moderate-to-high exercise intensities that are associated with cardio-respiratory benefits, the use of music appears to assuage the rapid deterioration of affect and promotes situation-specific motivation (see e.g., Hutchinson et al., 2011).

The present findings indicate that music per se is likely to promote ~10% more dissociation at moderate-to-high exercise intensities. This is noteworthy as it is at these intensities that the general population can derive significant cardiorespiratory benefits from exercise (Ekkekakis & Acevedo, 2006). An obstacle to exercise adherence for many people is the negative affect that is experienced close to and beyond ventilatory threshold (Hall, Ekkekakis, & Petruzzello, 2002). The present findings indicate that moderate- and fast-tempo music reduced the number of associative thoughts and had a corresponding positive influence on affective valence. This small influence may be very significant in terms of exercise-related affect and adherence among the general population (Hall et al.). Moreover, the affective benefits of music seem to be particularly pronounced for women, as they reported higher affective valence scores in every music condition relative to control (see Table 2).

Conclusions and Recommendations

The cubic trajectory (two points of inflection) reported by Karageorghis et al. (2011) using cycle ergometry was not replicated in the present study using treadmill exercise. Rather a significant ($p < .05$) quadratic relationship emerged, which means that there was just one inflection point in the trendline (at 80% maxHRR; see Fig. 2). The trendline shows that at the highest exercise intensity (90% maxHRR) participants preferred music at ~131 bpm. The range of preferred tempi for treadmill exercise (123–131 bpm) was narrower than that for cycle ergometry (125–140 bpm). There is only a weak association between optimal selection of music tempo at various exercise intensities and a range of psychological outcomes (e.g., affective valence). The implication of this is that to optimize such outcomes, a tempo range as broad as 100–140 bpm might be considered by practitioners. One of the original contributions of this study is that it shows how asynchronous music reduces the number of associative thoughts at all exercise intensities by ~10%. Also, regardless of its tempo, music is less preferred at high intensities when compared to low-to-moderate intensities, which supports theoretical propositions (Rejeski, 1985; Tenenbaum, 2001).

Despite the fact that tempo appears to be a strong determinant of music preference, given the information processing demands that are placed by high-intensity exercise in particular (Rejeski, 1985), future research might examine music *complexity* (how predictable it is; see e.g., North & Hargreaves, 2008). Complexity could be coupled with music's affective valence and arousing properties to establish a more sophisticated approach by which to advance this line of research. One possible extension of the present protocol would be to examine the interactive effects of music tempo and intensity (volume) across exercise intensities in a similar vein to past studies (e.g., Copeland & Franks, 1991; Edworthy & Waring, 2006). Moreover, given that our qualitative analysis indicated the lyrical content of music was easier to process at the lower intensities, it would be worthwhile to repeat the present protocol using tracks with lyrical and instrumental versions. Such a study might demonstrate that instrumental music is most appropriate for the highest intensities. Finally, gender differences should be further examined, and given the similar age range/athletic background of participants used in this line of studies, there is a need to extend the work to more diverse groups. Such an approach would allow researchers to gauge the degree to which the present findings generalize to the wider population.

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Table 1

Descriptive statistics for women and men combined for each dependent variable across six exercise intensities

		Feeling Scale		Felt Arousal Scale		State Attention		S FSS-2		IMI IE		IMI PT	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
40% HRR max	N	1.82	1.71	2.36	.66	77.59	23.56	32.32	3.51	3.36	1.09	1.70	.82
	S	2.27	1.42	3.09	.92	85.05	12.69	33.45	4.68	4.00	1.23	1.44	.50
	M	3.00	1.20	3.45	1.01	86.25	19.16	36.05	4.38	4.78	.90	1.26	.42
	F	2.64	1.26	3.14	.99	85.64	16.83	34.27	4.00	4.27	1.08	1.35	.47
	VF	2.82	1.47	3.09	1.06	82.68	15.17	35.09	4.40	4.41	1.17	1.48	.56
50% HRR max	N	1.09	1.63	2.59	.80	64.02	33.88	32.32	4.66	3.21	.98	1.95	.65
	S	2.50	1.60	3.32	.99	76.27	19.14	33.91	4.26	4.13	.97	1.77	.84
	M	3.45	.96	3.77	1.07	79.11	20.03	34.86	4.06	4.70	1.04	1.55	.66
	F	2.68	1.64	3.73	1.08	82.25	22.49	35.68	4.89	4.66	1.25	1.70	.90
	VF	2.59	1.44	3.14	.71	77.34	21.05	33.86	4.96	4.36	1.06	1.56	.63
60% HRR max	N	1.41	1.79	2.77	.87	63.18	29.63	32.77	4.91	3.49	1.12	1.99	.92
	S	2.45	1.34	3.73	1.03	72.98	20.02	34.77	4.86	4.64	.90	1.87	.63
	M	3.00	1.35	4.05	.84	67.91	21.38	34.86	4.31	4.79	.67	1.92	.95
	F	3.05	.95	3.86	.94	71.95	23.11	35.50	4.21	4.85	.96	1.69	.62
	VF	2.91	1.15	3.68	.95	70.43	19.84	34.86	4.30	4.72	.90	1.63	.58
70% HRR max	N	1.27	1.52	3.18	1.10	48.80	29.36	31.64	5.37	3.58	1.04	1.96	.73
	S	2.27	1.24	3.86	1.04	59.95	27.40	33.95	3.87	4.68	.71	1.78	.70
	M	3.27	.94	4.36	1.05	63.23	24.28	35.18	4.34	5.16	.84	1.86	.69
	F	2.73	1.20	4.23	.87	64.55	21.78	35.36	3.81	5.12	.98	1.85	.84
	VF	2.45	1.34	3.77	1.07	65.73	25.60	33.86	4.29	4.65	.97	1.89	.78
80% HRR max	N	.95	2.17	3.50	1.06	29.91	25.81	31.91	5.34	3.88	1.12	2.45	.93
	S	1.73	1.86	4.05	.79	54.95	28.04	33.91	4.41	4.58	1.07	1.92	.74
	M	2.27	1.67	3.95	1.00	53.39	25.03	35.41	4.19	4.79	.91	2.06	.75
	F	2.14	1.58	4.09	.68	47.23	22.75	34.77	4.96	4.79	.95	1.95	.73
	VF	1.32	1.91	4.09	.87	51.45	26.64	33.14	4.64	4.63	.89	2.15	.90
90% HRR max	N	– .36	2.13	4.05	1.05	16.68	20.10	31.32	5.38	3.74	1.18	3.10	.91
	S	.64	2.13	4.41	1.01	26.32	22.67	32.86	3.99	4.47	.94	2.71	1.10
	M	.68	1.89	4.32	.72	28.98	25.48	33.23	3.99	4.47	1.07	2.63	1.16
	F	.86	2.19	4.59	.85	32.61	27.64	34.95	4.34	4.61	1.04	2.56	.91
	VF	1.09	1.80	4.36	.90	32.48	25.12	33.59	4.76	4.54	.72	2.74	1.03

Note. S FSS-2 = Short Flow State Scale-2, IMI IE = Intrinsic Motivation Inventory Interest-Enjoyment, IMI PT = Intrinsic Motivation Inventory Pressure-Tension condition, N = No-music condition, S = Slow-tempo condition, M = Medium-tempo condition, F = Fast-tempo condition, VF = Very fast-tempo condition. A higher state attention score indicates a greater number of dissociative thoughts.

Table 2

Inferential statistics results for all dependent variables.

	Pillai's trace	*F*	df	*p*	η_p^2
Interaction effects					
Tempo preference					
Exercise intensity x music tempo x		.73	15, 300	.752	.03
Exercise intensity x gender		.60	5, 300	.702	.03
Music tempo x gender		1.01	3, 300	.393	.05
Exercise intensity x music tempo		1.86	6.43, 128.65	.088	.09
In-task affect					
Exercise intensity x music tempo x	.10	1.01	40, 800	.455	.05
Exercise intensity x gender	.09	.88	10, 200	.549	.04
Music tempo x gender	.24	2.78	8, 160	.007	.12
Exercise intensity x music tempo	.13	1.35	40, 800	.075	.06
State attention					
Exercise intensity x music tempo x		.91	20, 400	.575	.04
Exercise intensity x gender		1.07	5, 400	.383	.05
Music tempo x gender		.54	4, 400	.711	.03
Exercise intensity x music tempo		.849	8.08, 161.64	.562	.04
Motivation variables					
Exercise intensity x music tempo x	.15	1.01	60, 1200	.310	.05
Exercise intensity x gender	.13	.93	15, 300	.531	.04
Music tempo x gender	.39	3.02	12, 240	.001	.13
Exercise intensity x music tempo	.16	1.15	60, 1200	.206	.05
Main effects					
Tempo preference					
Exercise intensity		6.17	2.70, 54.11	.002	.24
Condition		6.49	3, 60	.001	.24
Gender		7.57	1, 20	.012	.27
In-task affect					
Exercise intensity	.87	15.36	10, 200	< .001	.43
Condition	.68	10.37	8, 160	< .001	.34
Gender	.11	1.20	2, 19	.324	.11
State attention					
Exercise intensity		54.29	2.16, 43.14	< .001	.73
Condition		6.60	1.80, 35.97	.006	.24
Gender		.20	1, 20	.656	.10
Motivation variables					
Exercise Intensity	.81	7.35	15, 300	< .001	.27
Condition	.64	5.44	12, 240	< .001	.21
Gender	.07	.46	3, 18	.717	.07

Table 3

Raw data themes (*k* = 31)	First-order themes (*k* = 5)	General dimensions (*k* = 2)
Enjoyed listening regardless of the intensity	Positive mood state	Enhanced exercise experience
I was pretty happy with the music throughout		
I wasn't worried how tired I was		
I prefer upbeat tracks because you get into it more		
The music gets you going	Arousal	
The music livened me up a little		
Felt a lot more springy		
Felt more distracted	Dissociation	
Takes your mind off the pain		
Low intensities completely distracted		
The music took my mind off running		
I was singing in my head		
The music helped me zone out		
The lyrics stood out		
Concentrating on the lyrics		
When you had no music at the highest intensity it was even worse		
The music makes you forget little niggles		
With the music, it was automatic, I didn't think about doing it		
Push yourself	Increased motivation	Behavioural responses to music
When running was harder the music helped me carry on		
I was not really motivated without music		
You can really get going to *Stronger*		
Words making me go for it		
Music is going to help you most at the highest intensities		
I think I changed my steps with the music	Entrainment	
Linked to how I run		
My experience of the music depended on how quick I was going		
Mismatch in beat and movement		
It was easier to run along with music		
I like to run to the rhythm		
If you're running fast, then Chase and Status helps you go a little bit more		

Results of the inductive content analysis

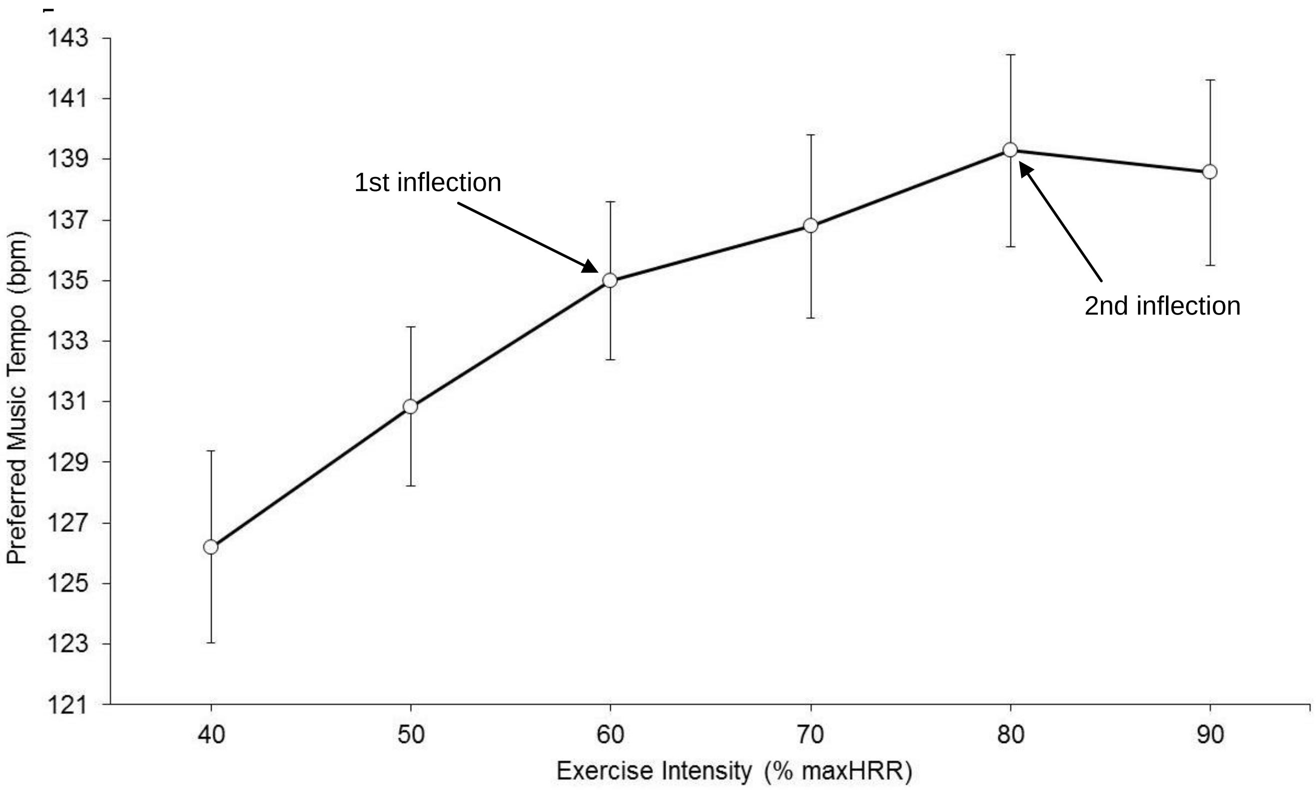

Fig. 1. The cubic relationship between exercise heart rate and preference for music tempo reported by Karageorghis et al. (2011). Reproduced with permission from *Research Quarterly for Exercise and Sport*, Vol. 82, No. 2, 274–284, Copyright (2011) by the American Alliance for Health, Physical Education, Recreation and Dance, 1900 Association Drive, Reston, VA 20191.

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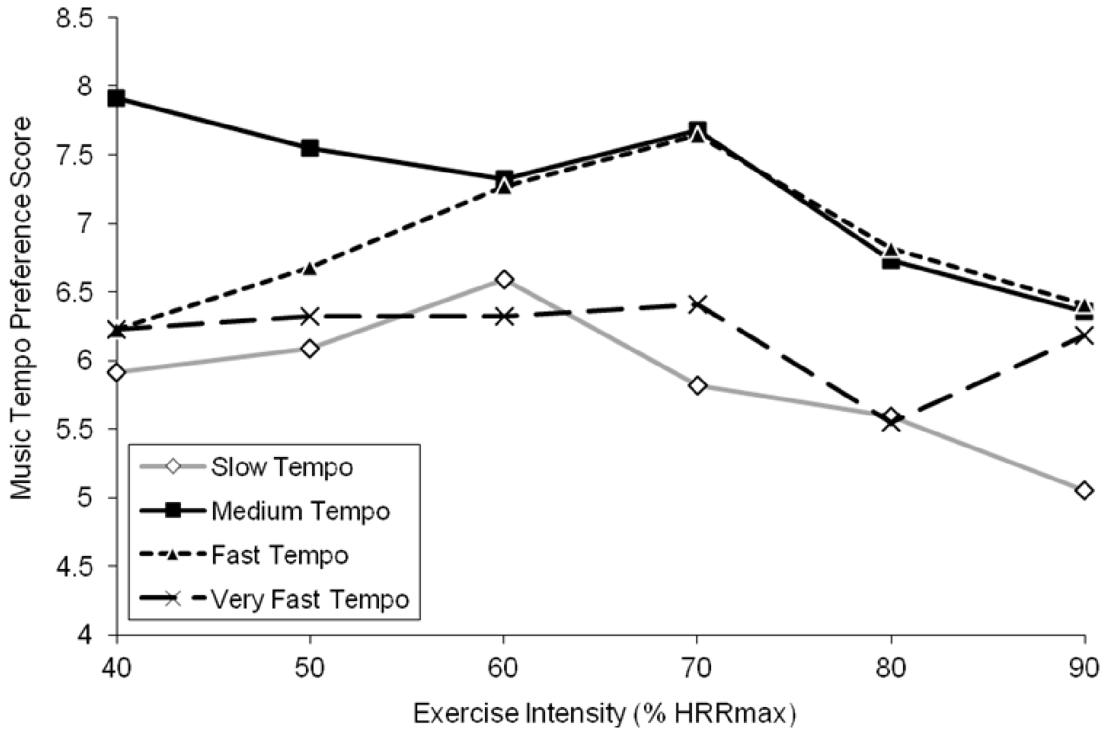

Fig. 2. Trendlines for music tempo preference ratings across exercise intensities.

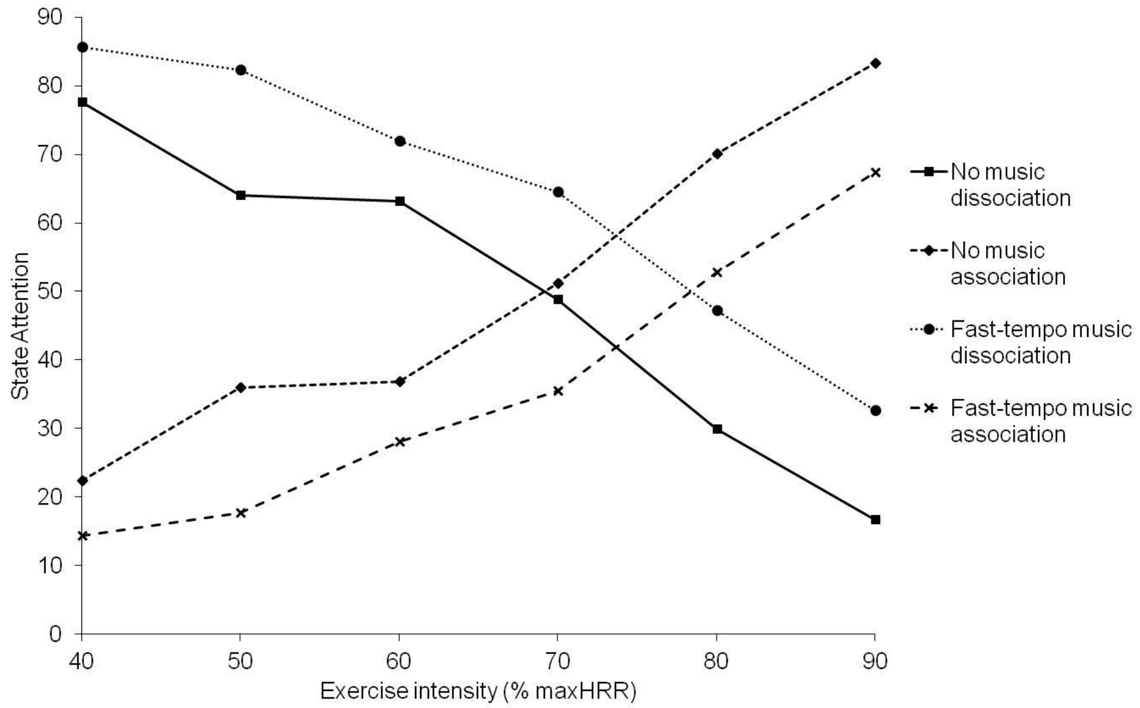

Fig. 3. Comparison of state attention scores across all exercise intensities between no-music control and fast-tempo music conditions.