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Revisiting the Exercise Heart Rate-Music Tempo Preference Relationship

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Abstract

In the present study, we investigated a hypothesized quartic relationship (meaning three inflection points) between exercise heart rate (HR) and preferred music tempo. Initial theoretical predictions suggested a positive linear relationship (Iwanaga, 1995a, 1995b); however, recent experimental work has shown that as exercise HR increases, there may be step-changes and plateaus that punctuate the profile of music tempo preference (Karageorghis, Jones, & Stuart, 2008). Tempi bands consisted of slow (95-100 bpm), medium (115–120 bpm), fast (135–140 bpm), and very fast (155–160 bpm) music. Twenty-eight active undergraduate students (mean age = 20.6 years, *SD* = 0.9) cycled at exercise intensities representing 40, 50, 60, 70, 80, and 90% of their maximal HR reserve while their music preference was assessed using a 10-point scale. The Exercise Intensity x Music Tempo interaction was significant, $F(6.16, 160.05) = 7.08$, $p < .001$, $\eta_p^2 = .21$, as was the test for a quartic trajectory in the exercise HR–preferred music tempo relationship, $F(19, 648) = 10.56$, $p < .001$. Whereas slow tempo music was not preferred at any exercise intensity, preference for fast tempo increased, relative to medium and very fast tempo music as exercise intensity increased. The implications for the prescription of music in exercise and physical activity contexts are discussed.

Key words: Asynchronous music, quartic relationship, meter, music selection

Introduction

Numerous studies in the last decade have addressed the impact of music either as an ergogenic aid or as a means by which to regulate affective responses to exercise (e.g., Edworthy & Waring, 2006; Lim, Atkinson, Karageorghis, & Eubank, 2009; Rendi, Szabo, & Szabo, 2008). Such work has been inspired by theoretical advances within the domain of exercise psychology (Karageorghis, Terry, & Lane, 1999; Karageorghis & Terry, 2009) as well as a proliferation in the use of personal listening devices such as the *iPod*™, which facilitate the construction of personal playlists. Due to its proposed influences on psychological responses during exercise and, ultimately, exercise adherence, carefully selected music may positively affect public health and is therefore an important area of study (Karageorghis, 2008; Schwartz, Fernhall, & Plowman, 1990).

Since the publication of a conceptual model underlying the use of music in exercise and sport contexts (Karageorghis et al., 1999) and an instrument—the Brunel Music Rating Inventory (BMRI)—which operationalized the model to facilitate more purposeful music selection (Karageorghis et al., 1999; Karageorghis, Priest, Terry, Chatzisarantis, & Lane, 2006), a body of evidence has evolved which shows that the appropriate use of music can elicit a number of measurable benefits. For example, background or asynchronous music has been shown to reduce perceived exertion by ~10% (Nethery, 2002), elevate in-task affect (even at high intensities) (Elliot, Carr, & Orme, 2005), and enhance endurance (Rendi et al., 2008). Synchronous music, wherein work rate is coordinated with the rhythmical qualities of the music, has been shown to elicit a strong ergogenic effect in both submaximal (Karageorghis, Mouzourides, Priest, Sasso, Morrish, & Walley, 2009) and maximal tasks (Simpson & Karageorghis, 2006).

With reference to the application of asynchronous music, which is the focus of the present study, there has been ongoing debate among researchers and exercise professionals as to how exercise heart rate should relate to the prescribed tempo or speed of a piece of music (Gfeller, 1988; Karageorghis, Jones, & Low, 2006; Karageorghis, Jones, & Stuart, 2008; LeBlanc, 1995). Tempo, which is measured in beats per minute (bpm), is the musical quality that is easiest to manipulate (other than intensity/volume). It is a major determinant of one's psychophysical and aesthetic response to a piece of music (e.g., Bishop, Karageorghis, & Kinrade, 2009; Edworthy & Waring, 2006).

Preference for different music tempi should be affected by the physiological arousal of the listener and the context in which the music is heard; when the individual's arousal is high, faster tempi are preferred (Berlyne, 1971; North & Hargreaves, 2008, pp. 115–116). Also, in situations where high arousal is likely to facilitate performance, faster tempi are likely to be preferred (e.g., Rendi et al., 2008). Accordingly, there might be a stronger preference for fast tempo music during physical activity.

Researchers have found support for the hypothesis that people prefer auditory stimuli with tempi within the range of normal heart-rate patterning during everyday activity (e.g., 70–100 bpm; Iwanga, 1995a). Iwanaga (1995b) examined the expected linear relationship between HR and music tempi preferences and found a significant positive relationship. However, participants in this study were able to self-regulate tempo, which does not reflect how people typically listen to music. Iwanaga's (1995a, 1995b) work came under criticism from LeBlanc (1995) who argued that the methodologies lacked external validity. He suggested that Iwanaga's findings could be validated by having the same group of participants select their preferred tempi at varying work intensities. This prompted Karageorghis and his collaborators to carry out two experiments examining the relationship between HR and music tempo preference in an exercise context (Karageorghis, Jones et al., 2006; Karageorghis et al., 2008).

Karageorghis, Jones et al. (2006) examined the relationship between exercise HR and preferred tempo. Participants reported their preference for slow (80 bpm), medium (120 bpm), and fast (140 bpm) tempo music selections in each of three treadmill walking conditions at 40, 60, and 75% of maximal heart rate reserve (HRRmax). A significant and large main effect for music tempo was found, wherein a general preference for fast and medium tempo music over slow music was evident (η_p^2 = .78). An Exercise Intensity x Music Tempo interaction effect of a moderate order was also observed (η_p^2 = .09), with participants reporting a preference for either fast or medium tempo music during low and moderate exercise intensities, but fast tempo music during high intensity exercise.

Karageorghis et al. (2008) extended this line of enquiry by administering entire music programs, rather than single musical excerpts, to participants. The genesis of this study was an earlier suggestion that, despite the reported preference for fast tempo music at high exercise intensity, continued exposure to such music may result in negative psychological outcomes such as boredom and irritation due to the lack of variety (Karageorghis, Jones et al., 2006). Accordingly, Karageorghis et al. administered medium, fast, and mixed tempi conditions (tracks arranged in the order medium-fast-fast-medium-fast-fast) in addition to a no-music control, while participants walked on an inclined treadmill at 70% HRRmax. Dependent measures included music preference ratings, three Intrinsic Motivation Subscales (interest-enjoyment, pressure-tension, and effort-importance), and global flow. The mixed-tempi condition was expected to yield the most positive motivation outcomes; however, this hypothesis was refuted as the medium tempi condition yielded the most positive outcomes. The authors suggested the possibility of a step change in preference between 70% and 75% HRRmax, at which point participants express a greater preference for fast tempo music. This is also the point at which energy production becomes more reliant on anaerobic as opposed to aerobic pathways. Accordingly, participants become more acutely aware of physiological sensations (Rejeski, 1985; Tenenbaum, 2001). Indeed, Ekkekakis, Hall, and Petruzello (2004) reported that when exercise intensity exceeded the ventilatory threshold, there were curvilinear declines in pleasure.

Following the inconclusive and somewhat unexpected results of the first two studies, the present study addressed the exercise HR–music-tempo-preference relationship using a more exacting methodological approach. The proportional linear relationship between HR and music tempo preference that was proposed by Iwanaga (1995a, 1995b) is not expected to emerge. Rather, the collective evidence (i.e., Karageorghis, Jones et al., 2006; Karageorghis et al., 2008) points towards a non-linear relationship between exercise HR and music tempo preference. One possibility is that of a *quartic* relationship (i.e., there are three bends or “inflection points”, which result in two shallow steeper phases; Karageorghis & Terry, 2009; see Figure 1).

During the early stages of an exercise bout, there is linearity in the relationship; thereafter, during moderate-to-high intensity exercise, both medium and fast tempi are preferred; and this leveling of the trend line constitutes the first inflection point. Beyond 75% HRRmax, fast tempi are preferred and the linearity of the relationship is resumed (second inflection point). It is probable that music tempo preferences plateau at higher intensities of exercise (i.e., > 80% HRRmax); this flattening of the trend line or “ceiling effect” constitutes the final inflection point. This may be due, in part, to the lack of familiarity of such high tempi in everyday listening situations (Berlyne, 1971; Karageorghis, Priest, et al., 2006; Karageorghis et al., 1999). No study to date has examined the exercise HR–music-tempo-preference relationship using exercise intensities beyond 75% HRRmax, so the purpose of the present study was to examine preference for a wide range of tempi over exercise intensities that span 40–90% HRRmax (in

10% intervals), as well as preference at rest. It was hoped that this approach would provide insight as to the trajectory of the relationship and enable the research team to make more accurate recommendations to practitioners working in the domain of exercise and sport. While the short duration of the exercise bouts slightly limits the external validity of the present study, it does facilitate a full examination of the research question. The major potential contribution of this study is that it will enable exercise practitioners to better prescribe musical selections for different exercise intensities and aid participants in self-selection. By understanding the relationship between exercise HRate and music tempo preference, the beneficial effects of music as a motivator, affect enhancer, and ergogenic aid may be harnessed more fully (Karageorghis et al., 2008). A secondary aim was to explore whether the relationship was moderated by gender.

Method

Stage 1: Music Selection

Participants and procedure. A sample of 147 volunteer sport science undergraduates from two universities in southeast England, UK (60 women and 87 men; *M* age = 19.3 years, *SD* = 1.9) were used to identify a pool of possible musical selections for use in the experimental protocol of Stage 2. The participants in each stage of this study provided written informed consent and were similar in terms of age (18–22 years), ethnicity (Caucasian), and sociocultural background (brought up in the UK; see Karageorghis & Terry, 1997).

Participants recorded their five favorite pieces of music for an exercise context in order of perceived speed of each piece (from slowest to fastest); at least one of the selections had to be from the *rock* idiom. Subsequently, the selections were classified into the *rock* and *pop* idioms (to give experimental participants a choice) while other idioms were excluded. The 16 most frequently recorded tracks in each idiom were subjected to further testing. Thus, four tracks were used at each of four tempi: slow (95–100 bpm), medium (115–120 bpm), fast (135–140 bpm), and very fast (155–160 bpm).

A panel of eight (2 women and 6 men, *M* age = 20.6 years, *SD* = 1.1) purposively selected undergraduate sport sciences students from a university in south-east England, rated the motivational qualities of 32 tracks (16 from each idiom with four from each tempo) using the Brunel Music Rating Inventory-2 (BMRI-2: Karageorghis, Priest, et al., 2006). The tempo item was omitted from the BMRI-2, as tempo formed an independent variable in the present design. A 90 s excerpt of each track was used to include at least one verse and chorus. The panel rated the motivational qualities of each track with reference to a cycle ergometry task in accordance with the instructions of Karageorghis, Priest et al. (2006). This procedure was undertaken to ensure that, although the tempi between tracks differed, there would be homogeneity in terms of the music's other motivational qualities of the music (e.g. melody, harmony, lyrical affirmations, extra-musical associations) so that this factor did not present a threat to internal validity.

Tracks that had similar motivational quotients at each of the four required tempi ranges were copied onto CDs. Therefore, four CDs were created with one for each idiom (*k* = 2) and one for each experimental trial (*k* = 2). Each CD contained four tracks, with one track at each of the required tempi ranges. The tracks from each idiom were repeated on each CD four times so that they could be played while participants rested on the cycle ergometer (baseline measure) and then exercised at six intensities (40, 50, 60, 70, 80, and 90% HRRmax). These six intensities were administered over two exercise bouts: in Trial 1, participants exercised at 40, 60, and 80 HRRmax, while in Trial 2 they exercised at 50, 70, and 90% HRRmax. The presentation of tracks, administration of exercise intensities, and order of trials were fully counterbalanced.

Copyright permission was obtained from the music publishers to record the tracks for research purposes (see Table 1).

Stage 2: Experimental Investigation

Power analysis. A power analysis was conducted to establish appropriate sample size, and based on a moderate effect size for the Exercise Intensity x Music Tempo preference interaction (partial η^2 =.09; Karageorghis, Jones et al., 2006), approximately 24 participants would be required. An extra four participants were recruited to protect the study against the possibility of experimental dropout and case deletions due to outliers.

Participant characteristics. The participants comprised 13 women and 15 men (mean age = 20.6 years, *SD* =.90) from the body of sport sciences undergraduates at Brunel University. Participants were drawn from sports that have a significant requirement for aerobic energy production (e.g., outfield players from weight-bearing sports). Furthermore, cyclists or elite road running/track/cross-country athletes were not employed in order to maintain some homogeneity in terms of aerobic fitness. Individuals who cycled $\geq$ 10 miles per week were not eligible. As an aid to recruitment, participants' names were entered into a raffle for an item of sports apparel.

Apparatus and measures. A cycle ergometer (Monark 874E; Monark Exercise AB, Vansbro, Sweden) was used for testing along with a wall-mounted stereo system (Tascam CD-A500; TEAC Corp., Tokyo, Japan) and a decibel meter (GA 102 Sound Level Meter Type 1; Castle Associates, Scarborough, UK) to standardize music intensity at 75 dBA. This sound pressure level (volume) would typify most exercise facilities but still lie within safe limits from an audiological perspective. Target HR was assessed by use of a HR monitor attached to the sternum of each participant and a sensor (Polar Accurex Plus; Polar Electro, Kempele, Finland) held by one of the experimenters. Tempo preference at each of the six work intensities was assessed using a single item developed by Karageorghis, Jones, et al. (2006) and further tested by Karageorghis et al. (2008). The item was modified slightly to suit the present protocol in the following manner: “Rate your preference for this track based on how you feel right now” (as opposed to “based on the work level you have just experienced”) with responses provided on a 10-point scale anchored by 1 (*I do not like it at all*) and 10 (*I like it very much*). The term “preference” used in the item can be interpreted as being synonymous with the degree of liking for each track as was the case in the two preceding studies (Karageorghis, Jones, et al., 2006; Karageorghis et al., 2008). For the baseline measurement at rest, the same item was administered across both sets of experimental trials, thus ensuring equivalence between them. To prevent participants from becoming aware of the precise purpose of the study, no reference was made to tempo (i.e., “Rate your preference for the tempo of this track…”). The obviation of this clear threat to internal validity and the careful control of other motivational qualities (excepting tempo) was felt to sufficiently justify the practice of assaying generic music preference rather than tempo preference.

Pre-test. Ethical clearance was obtained for the study from the Brunel University Research Ethics Committee. Participants were required to cycle on the ergometer at a constant speed of 75 revolutions per minute (rpm), and weights were gradually added to the ergometer weight basket (100 g and 500 g denominations) to elicit work intensities of 40, 50, 60, 70, 80, and 90% HRRmax. The weights initially placed in the weight basket corresponded with each participant’s 30% HRRmax. To establish participants’ maximal HR, they completed an incremental cycle ergometer test to voluntary exertion (Lucía et al., 2006). Following a 2-min warm up, participants were required to maintain a speed of 75 rpm, and the researchers added a weight of .5 kg every minute, until voluntary exhaustion. In calculating exercise HR for each work intensity, HRR was established by application of the Karvonen formula. This enabled the research team to standardize work intensity across participants. In applying the formula, resting HR was assessed when each participant arrived for the pretest, after they had sat quietly in a comfortable chair for 5 min.

Habituation trial. Each participant was habituated to the cycle ergometry task so as to familiarize them with the experimental task and reduce the possibility of practice effects (Harris, 2008, pp. 156–157). Weight was added to increase pedal resistance rather than requiring the participant to increase their pedal rate. The rationale for this procedure was to prevent any potential synchronization of pedal rate and music tempo (see e.g., Anshel & Marisi, 1978). A music tempo of 150 bpm was avoided; because it could result in synchronization effect. Participants spent ~20 min on the cycle ergometer during the habituation trial, during which time the experimental protocol was explained. Thus, the experimenters met each participant on four occasions: (a) for a pre-test to establish their maximal HR, (b) once for a habituation session, and (c) twice for each segment of the experimental protocol (40, 60, and 80% maxHRR or 50, 70, and 90% HRRmax).

Experimental trial. There were two experimental trials for each participant during which they were tested at 40, 60, and 80% HRRmax or at 50, 70, and 90% HRRmax. The order in which they were requested to cycle at these intensities was counterbalanced (between and within trials) to guard against any potential order effects. Participants were required to follow identical patterns of activity (no other vigorous physical activity permitted) and diet before the trial on the day of the pretest and on the days of the experimental trials (Harris, 2008, p. 134). This was in concert with the procedure followed in two previous studies (Karageorghis, Jones, et al., 2006; Karageorghis et al., 2008). Furthermore, they were asked not to eat within 2 hr prior to testing. Each participant engaged in the trial individually in the presence of a same-sex researcher (cf. Anshel & Marisi, 1978).

Prior to administration of the experimental trial, participants were given a choice of either rock (*n* = 12) or pop (*n* = 16) music and the selections previously rated by their peers were delivered accordingly. While cycling on the ergometer, participants were asked to look straight ahead at a large blank screen positioned immediately in front of them. The rationale for this was to negate the influence of any visual stimuli on their responses to the music. Music intensity was standardized at 75 dBA for each of the four tracks by use of a decibel meter.

Tempo preferences and HR were taken at rest in each experimental trial. These measures were used to ensure that there were no differences in these variables between the two trials in which the six exercise intensities would be administered, but they were excluded from the main analysis. Participants performed a 5-min warm-up at a speed of 55 rpm with no music and then cycled at a constant speed of 75 rpm for the duration of each music-preference testing trial. The experimenter selected the appropriate exercise intensity (either 40, 50, 60, 70, 80 or 90% HRRmax) by adding or removing either 100 g or 0.5 kg disc at 30-s intervals to the weight basket of the cycle ergometer until target HR (± 2 bpm) was reached and maintained for a period of 30 s.

All musical selections included one verse and one chorus, and were of approximately 90 s in duration. Participants maintained steady state for 30 s at the prescribed exercise intensity; subsequently, they heard and responded to four 90-s musical excerpts with a 30-s period of silence between each. In cases where the tracks deviated slightly from the required tempi (95-100 bpm, 115-120 bpm, 135-140 bpm, and 155-160 bpm), they were digitally altered during recording to correspond with the required tempo. Previous work indicates that tempo changes of ± 4 bpm are indiscernible among nonmusicians (Levitin & Cook, 1996). A decision was made to include gaps of 15 bpm between the tempi ranges to render the musical selections clearly discernible from each other in terms of tempo, and to facilitate comparison with similar past research (Karageorghis, Jones, et al., 2006; Karageorghis et al., 2008).

Ten seconds before the end of each track, participants were asked to rate their preference for the piece of music based on a "how you feel right now" response set. Thereafter, a 30 s filler was used during which participants were required to count backwards from 100. The purpose of this procedure was to avoid any potential carry-over effect between experimental conditions. The entire procedure was repeated until the four tracks at the four different tempi were rated. The same musical idiom was used for all intensity levels in each of the two experimental trials. During testing at 90% HRRmax, some minor downward adjustment in resistance was necessary to prevent excessive elevation of HR. Participants performed a 5 min cool-down at the end of each trial. The total time spent by each participant at the three exercise intensities within a trial was ~8 min, and the trials were of ~35-min duration.

The menstrual cycle phase and the associated variation in female steroid hormones can influence athletic performance (Lebrun, McKenzie, Prior, & Taunton, 1995) and mood (Cockerill, Nevill, & Byrne, 1992). Accordingly, female participants were not tested during menstruation (the first five days of the follicular phase of the menstrual cycle) and were encouraged to provide the female experimenters with details of their menstrual cycle.

Data Analysis

Data were screened for univariate outliers using z scores > $\pm$ 3.29 and for multivariate outliers using the Mahalanobis distance method with $p < .001$ (Tabachnick & Fidell, 2007, pp. 68–69). There was a single dependent variable, music tempo preference, and three independent variables: exercise intensity (40, 50, 60, 70, 80, 90% HRRmax), music tempo (slow, medium, fast, and very fast), and gender. Thus, after checks to ensure that the data were suitable for parametric analysis, a mixed-model 6 x 4 x 2 (Gender x Exercise Intensity x Music Tempo) ANOVA was applied to the preference data. In addition, a mixed-model (Time x Music Tempo) ANOVA was used to check whether preferences differed at rest between the two experimental trials. Following appropriate reconfiguration of the data, a significance value ($p < .05$) relating to a quartic relationship was examined using an independent samples one-way ANOVA.

Results

Checks for univariate and multivariate outliers indicated that the dataset was free of outliers. Tests of the distributional properties of the data in each analysis cell ($k = 48$) revealed one minor violation for the combined women's and men's sample at 70% HRRmax with fast tempo music (std. skewness > + 2.58), one minor violation for the men's sample at 60% HRRmax with very fast tempo music (std. skewness > - 2.58), and one major violation for the men's sample at 80% HRRmax with very fast tempo music (std. kurtosis > + 3.29). As there was only one major violation in 48 cells, the authors decided not to apply logarithmic transformation to the entire dataset (see Tabachnick & Fidell, 2007, pp. 86–69).

Mauchly's test indicated a violation of the sphericity assumption for the Intensity x Music Tempo interaction, Mauchly's $W = .00$, $\varepsilon = .41$, $p < .001$, the intensity main effect, Mauchly's $W = .09$, $\varepsilon = .49$, $p < .001$, and the tempo main effect, Mauchly's $W = .29$, $\varepsilon = .58$, $p < .001$. Greenhouse-Geisser adjustments were applied accordingly. Collectively, the diagnostic tests indicated that the assumptions underlying a two- and three-way mixed-model ANOVA were satisfactorily met. The test of music preference at rest between the two experimental trials confirmed that there were no significant differences, $F(3, 25) = .33$, $p = .345$, $\eta_p^2 = .04$.

Two visualizations were created to aid interpretation: Figure 2 depicts the mean tempo-preference ratings across exercise intensities, whereas Figure 3 shows the mean of the preferred tempi at each exercise intensity. This latter visualization, while an imperfect representation of preference, allows for a better examination of the relationship between exercise HR and music tempo preference.

Interaction Effects

The higher-order interaction of Gender x Exercise Intensity x Music Tempo was nonsignificant, $F(15, 12) = .68$, $p = .802$, $\eta_p^2 = .03$, as were the two-way interactions of Gender x Exercise Intensity, $F(2.47, 160.05) = .50$, $p = .646$ $\eta_p^2 = .02$, and Gender x Music Tempo, $F(3, 390) = 1.99$, $p > .05$, $\eta_p^2 = .123$. The two-way interaction of Exercise Intensity x Music Tempo was significant (see Figure 2), $F(6.16, 160.05) = 7.08$, $p < .001$, $\eta_p^2 = .21$, and accounted for 21% of the variance in music tempo preference. This interaction was also associated with a significant linear $F(22, 648) = 9.37$, $p < .001$, quadratic $F(21, 648) = 9.74$, $p < .001$, cubic $F(20, 648) = 10.15$, $p < .001$, and quartic trajectory $F(19, 648) = 10.56$, $p < .001$. The quartic relationship (see Figure 3) was only marginally stronger than the cubic relationship (two points of infection), while the same applies in comparing the quadratic against the cubic relationship.

An examination of within-participants contrasts for Exercise Intensity x Music Tempo using standard errors to identify reliable differences and Bonferroni adjustments to protect against experimentwise error, indicated that, at 40% HRRmax, there were differences in music tempo preference between slow tempo and both medium and fast tempi as well as between fast and very fast tempi (see Table 2 and Figure 2). At 50% HRRmax, there were music tempo preference differences between slow tempo and all other tempi, between medium and very fast tempi, and between fast and very fast tempi. At 60% HRRmax, there were differences between slow tempo and all other tempi, between medium and very fast tempi, and between fast and very fast tempi. At 70% HRRmax, there were differences between slow tempo and all other tempi and between medium and fast tempi. At 80% HRRmax, there were differences between slow tempo and all other tempi. At 90% HRRmax, there were differences between slow tempo and all other tempi as well as between medium and fast tempi.

Main Effects

The main effects indicated no significant differences in exercise intensity, $F(2.47, 64.28) = 2.43$, $p = .084$, $\eta_p^2 = .08$, or sex, $F(1, 26) = 2.43$, $p = .131$, $\eta_p^2 = .09$. There was however a significant main effect for music tempo, $F(1.73, 44.96) = 15.56$, $p < .001$, $\eta_p^2 = .37$, which accounted for 37% of the variance in music preference. Pairwise comparisons indicated that the slow tempo music was least preferred when compared to medium, 95% C.I. = -2.60 to -.88, $p < .001$, fast, 95% C.I. = -3.13 to -.84, $p < .001$, and very fast tempo music, 95% C.I. = -2.80 to -.31, $p = .009$ (see Table 2).

Discussion

The primary aim of the present study was to test the hypothesized quartic relationship between exercise HR and music tempo preference, while a secondary aim was to explore whether the relationship was moderated by gender. The strong main effect for music tempo ($\eta_p^2 = .37$) demonstrates that this musical quality plays an important role in determining music preference during exercise. This result is in concert with theoretical predictions regarding the nature of the physiological arousal-music tempo relationship (e.g., Iwanaga, 1995a, North & Hargreaves, 2008, pp. 270, 294). As hypothesized, there was a quartic relationship ($p < .001$) between exercise HR and music tempo preference, although it is noteworthy that the test for a cubic relationship was equally significant ($p < .001$). Gender had no moderating influence on the relationship, which mirrors the findings of recent studies (Karageorghis, Jones, et al., 2006; Karageorghis et al., 2008).

With reference to the significant Exercise Intensity x Music Tempo interaction, the slow tempo music was inappropriate at all exercise intensities while the very fast tempo music elicited relatively lower music preference ratings at the low intensities; these findings mirror those of similar studies (e.g., Karageorghis, Jones, et al., 2006; Karageorghis et al., 2008). At the mid-range intensities of 50–60% HRRmax, the observed differences in music preference between the medium and fast tempi conditions were similar to those reported by Karageorghis, Jones, et al., in that fast tempo music was preferred.

At lower exercise intensities, the relationship between exercise HR and music tempo preference was positive and linear (see Figure 3). As exercise intensity increased, the first instance of nonlinearity is an inflection point at 60% HRRmax (see Figure 3). This is consistent with the results reported by Karageorghis, Jones, et al. (2006) and can be explained by the fact that the majority of up-tempo pop, rock, and dance music falls into a band of 115–140 bpm. Karageorghis et al. (2008) suggested that there might be a "step change" in preference between 70% and 75% HRRmax, which is close toward the level of intensity typically associated with the ventilatory or lactate threshold; after this point there is a closer relationship between physiological variables and rating of perceived exertion (Ekkekakis et al., 2004; Rejeski, 1985; Tenenbaum, 2001). The present findings do indicate a step change, albeit far less pronounced than that which was hypothesized (see Figure 3).

The third inflection point in the relationship between exercise HR and music tempo preference is caused by attenuation in music tempo preference at higher exercise intensities (i.e., > 80% HRRmax). Owing to the normal distribution of music tempi, relatively few pieces are recorded at the highest end of the tempi spectrum. Such faster pieces may contain too much information for the limited attentional capacity of the afferent nervous system (see Rejeski, 1985; Tenenbaum, 2001) or an arousal potential that is too great for the listener, even if they are in a state of heightened excitement (Berlyne, 1971). These psychobiological factors may be compounded by the expectancy that music typically falls within a certain range of tempi (North & Hargreaves, 1997). Accordingly, extremely fast pieces, as well as being too complex and overarousing may also be unfamiliar; a factor that is thought to strongly determine music preference (Berlyne; Karageorghis et al., 1999). The concomitant influence of such factors may explain the attenuation in music-tempo preference at higher exercise intensities; once relatively high exercise intensity is reached (i.e., > 80% HRRmax), an increase in music tempo will not result in corresponding increases in preference ratings.

The aesthetic response to musical tempo during exercise appears to be similar for both sexes. What the present findings do not reveal is whether women and men respond differently to the more complex rhythmical features within music. Whereas tempo is an index of speed, rhythmical patterns might be responded to differently according to gender; indeed, women are socialized to develop a greater interest in dance and have been shown to exhibit a stronger preference, compared to men, for the rhythmical constituents of music (see Karageorghis et al., 1999).

The trajectory of the relationship between exercise intensity and music tempo preference depicted in Figure 3 (using recognized configured data) approximates the hypothesized quartic relationship predicted (see Figure 1); however, the trend is more akin to a cubic relationship. We suggest that explaining it as such to practitioners is preferred owing to the relative simplicity of a cubic trajectory (i.e., “there is a linear rise in preferred music tempo across low-to-moderate exercise intensities, a leveling out at moderate-to-high intensities, and then a slight dip at 80% HRRmax”). The stabilization of music tempo preference that followed the first inflection point occurred at a higher exercise intensity than predicted (Karageorghis & Terry, 2009). This means that a positive linear relationship spanned a greater range of submaximal exercise intensities than was forecast. Furthermore, the stabilization itself (represented by the first plateau in the line; see Figure 3) applied to a much smaller range of exercise intensities than projected. This stabilization at moderate exercise intensities (60–70% HRRmax) may have occurred because certain participants did not wish to work at a very high intensity (cf. Ekkekakis et al., 2004). Hence, in an attempt to maintain or slightly reduce workload, they expressed a preference for music of medium tempo.

The step change in music tempo preference occurs, as predicted, at around 70–75% HRRmax, but it was less pronounced than expected, indicating a resumption of the positive linear relationship that was found at lower exercise intensities. The attenuation which occurs after the third inflection point is even more pronounced than the estimate (see Figure 1). As with the first plateau, this tendency may reflect participants' desire to exercise at a lower intensity level. It may also 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). Despite the statistical significance of the quartic and cubic trajectories ($p < .001$), the visualization depicted in Figure 3 ostensibly displays a cubic relationship. As alluded to earlier, this "ceiling effect" evident at very high exercise intensities should inform music-related interventions, whereas promotion of a quartic trajectory in selecting music tempi may represent an over-complication.

The music tempi preferences as reported were compressed into a much narrower band than the original prediction (Figure 1). Thus, although the range of exercise intensities assayed covers almost the entire submaximal range, the span of preferred music-tempi is relatively small (approximately 125–140 bpm). Accordingly, the slope of the relationship is less acute than expected (see Figure 1 and Figure 3), a finding that contrasts starkly with earlier propositions (e.g., Iwanaga, 1995a, 1995b). The present findings indicate a narrow band of preferred music tempi that is not as directly proportionate to exercise intensity as had previously been thought.

Limitations of the Present Study

Although the authors went to considerable lengths to ensure parity in the motivational qualities of the tracks, both across tempi bands and between idioms, the slow selection in the pop category (*Valerie* by Mark Ronson ft. Amy Winehouse, 2007) received considerable airplay on TV and radio in the months during which the experimental phase of the study took place. This occurrence aptly illustrates that such experiments can rarely be conducted in a "social vacuum"; it is inevitable that sociopsychological variables such as media reinforcement will have a bearing on the results (North & Hargreaves, 2008, p. 80). A minor limitation concerns the issue that aspects of rhythmical structure other than tempo were not controlled for in the present study. The pulse or "beat" as felt by the listener may differ from the tempo; this explains why some slower pieces can be perceived as much faster due to the particular meter or rhythms employed.

The preference item used as the sole dependent variable in this study and two previous studies (Karageorghis, Jones, et al., 2006; Karageorghis et al., 2008) could be reworded for future use, given that participants are actually expressing the degree to which they *like* each track rather than placing tracks in rank order. A more appropriate item might be "Rate how much you like this track based on how you feel right now". To avoid the compound nature of this item, participants could be told to respond *each time* on the basis of "how they feel right now" (the response set) and then be administered the simpler item "Rate how much you like this track". Finally, the relatively short duration of the exercise bouts slightly curtails the external validity of the current study.

Conclusions and Recommendations

Taken collectively, the present findings underline the importance of exercise intensity in determining music tempo preference during exercise. The findings indicate that, while the relationship between exercise HR and music-tempo preference has linear aspects as predicted both by theorists (Iwanaga, 1995a, 1995b) and exercise practitioners (Gfeller, 1988), it is punctuated by nonlinear features as theorized by Karageorghis et al. (2008) and Karageorghis and Terry (2009). The quartic relationship that was found might be explained by recourse to psychomusicological (e.g., North & Hargreaves, 1997), psychobiological (e.g., Berlyne, 1971), and information processing (e.g., Rejeski, 1985; Tenenbaum, 2001) factors.

The present study did not consider individual difference factors and, in particular, how personality traits and training status might moderate the preference for music tempi during exercise. For example, the attenuation in music tempo preference at very high exercise intensities may not emerge among highly trained individuals. Also, this study did not assess enjoyment or other motivation outcomes alongside music preference. Given that previous findings showed that the highest preference ratings were associated with superior motivation outcomes (Karageorghis et al., 2008), it seems plausible that music preference is an important variable in shaping the exercise experience. Future researchers should seek to further investigate the link between music preference and a range of affective and motivation outcomes. Moreover, a replication of the present design using other exercise modalities (e.g., cycling, motorized stepping, dance aerobics, etc.) and longer exercise bouts be a worthwhile endeavor. By broadening the scope of the work to real-world exercise tasks and including relevant outcome measures, the implications of appropriate music selection for public health will become more apparent. With a better understanding of the most appropriate music tempo for various exercise intensities, practitioners, exercisers, and equipment manufacturers will be more able to harness the ergogenic and psychological effects of music.

When compared to previous findings (e.g., Karageorghis, Jones, et al., 2006; Karageorghis et al., 2008), the present findings have greater utility for those prescribing asynchronous music for exercise. For optimal effect, practitioners should aim to employ a narrow band of musical tempi (125–140 bpm) when working with those exercising in the low-to-moderate range of exercise intensities (40–70% HRRmax). Slower tempi (< 100 bpm) do not appear to be appropriate for any exercise intensity. Practitioners should be mindful of the plateau in the exercise HR–tempo preference relationship, which occurs above 70–75% HRRmax. Beyond this intensity, the tempo should either be maintained or reduced slightly in accordance with the quartic trajectory. For those advising practitioners, we suggest that because the practical difference between the significant quartic and cubic relationships is negligible, the exercise HR–tempo preference relationship should be presented as being cubic in nature (two inflection points), with a linear progression in the early stages (125–135 bpm), followed by a leveling of the trend line from 60 to 80% HRRmax (135–140 bpm), then a plateau or “ceiling effect” beyond 80% HRRmax (see Figure 3). The present results indicate that fast tempi are most preferred during high intensity exercise although future work might explore whether at the point at which the body is shouting “stop”, silence is indeed “golden”.

References

Anshel, M. H., & Marisi, D. Q. (1978). Effects of music and rhythm on physical performance. *The Research Quarterly*, *49*, 109–113.

Berlyne, D. E. (1971). *Aesthetics and psychobiology*. New York: Appleton Century Crofts.

Bishop, D. T., Karageorghis, C. I., & Kinrade, N. P. (2009). Effects of musically-induced emotions on choice reaction time performance. *The Sport Psychologist*, *23,* 59–76.

Cockerill, I. M., Nevill, A. M., & Byrne, N. C. (1992). Mood, mileage and the menstrual cycle. *British Journal of Sports Medicine*, *26*, 145–150.

Ebanks, R. (2000). Freestyler [Recorded by Bomfunk MCs]. On *In Stereo* [CD]. Helsinki, Finland: Sony Music.

Edworthy, J., & Waring, H. (2006). The effects of music tempo and loudness level on treadmill exercise. *Ergonomics*, *49*, 1597–1610.

Ekkekakis, P., Hall, E. E., & Petruzzello, S. (2004). Practical markers of the transition from aerobic to anaerobic metabolism during exercise: Rationale and a case for affect-based exercise prescription. *Preventive Medicine, 38*, 149–159.

Elliot, D., Carr, S., Orme, D. (2005). The effect of motivational music on sub-maximal exercise. *European Journal of Sport Science*, *5*, 97–106.

Gallagher, N. (1995). Wonderwall [Recorded by Oasis]. On *(What's The Story) Morning Glory?* [CD]. London: Creation Records.

Gfeller, K. (1988). Musical components and styles preferred by young adults for aerobic fitness activities. *Journal of Music Therapy*, *25*, 28–43.

Harris, P. (2008). *Designing and reporting experiments in psychology* (3rd ed.). Maidenhead, UK: Open University Press.

Howlett, L., Flint, K., Horn, A., Dudley, J., Jeczalik, P., Morley, G.,et al. (1996). Firestarter [Recorded by Prodigy]. On *The Fat Of The Land* [CD]. London: XL Recordings.

Iwanaga, I. (1995a). Relationship between heart rate and preference for tempo of music. *Perceptual and Motor Skills*, *81*, 435–440.

Iwanaga, I. (1995b). Harmonic relationship between preferred tempi and heart rate. *Perceptual and Motor Skills*, *81*, 67–71.

Karageorghis, C. I. (2008). The scientific application of music in sport and exercise. In A. M. Lane (Ed.), *Sport and exercise psychology* (pp. 109–137). London: Hodder Education.

Karageorghis, C. I., Jones, L., & Low, D. C. (2006). Relationship between exercise heart rate and music tempo preference. *Research Quarterly for Exercise and Sport*, *26*, 240–250.

Karageorghis, C. I., Jones, L., & Stuart, D. P. (2008). Psychological effects of music tempi during exercise. *International Journal of Sports Medicine*, *29*, 613–619.

Karageorghis, C. I., Mouzourides, D. A. Priest, D, Sasso, T. A., Morrish, D. J., & Walley, C. L. (2009). Psychophysical and ergogenic effects of synchronous music during treadmill walking. *Journal of Sport & Exercise Psychology*, *31*, 18–36.

Karageorghis, C. I., Priest, D. L., Terry, P. C., Chatzisarantis, N. L. D., & Lane, A. M. (2006). Redesign and initial validation of an instrument to assess the motivational qualities of music in exercise: The Brunel Music Rating Inventory-2. *Journal of Sports Sciences*, *24*, 899–909.

Karageorghis, C. I., & Terry, P. C. (1997). The psychophysical effects of music in sport and exercise: A review. *Journal of Sport Behavior*, *20*, 54–68.

Karageorghis, C. I., & Terry, P. C. (2009). The psychological, psychophysical and ergogenic effects of music in sport: A review and synthesis. In A. J. Bateman & J. R. Bale (Eds.) *Sporting sounds: Relationships between sport and music* (pp. 13–36). London: Routledge.

Karageorghis, C. I., Terry, P. C., & Lane, A. M. (1999). Development and initial validation of an instrument to assess the motivational qualities of music in exercise and sport: The Brunel Music Rating Inventory. *Journal of Sports Sciences*, *17*, 713–724.

LeBlanc, A. (1995). Differing results in research in preference for music tempo. *Perceptual and Motor Skills*, *81*, 1253–1254.

Lebrun, C. M., McKenzie, D. C., & Prior, J. C., & Taunton, J. E. (1995). Effects of menstrual cycle phase on athletic performance. *Medicine and Science in Sports and Exercise*, *27*, 437–444.

Levitin, D. J., & Cook, P. R. (1996). Memory for musical tempo: Additional evidence that auditory memory is absolute. *Perception and Psychophysics*, *58*, 927–935.

Lim, H. B. T., Atkinson, G., Karageorghis, C. I., & Eubank, M. M. (2009). Effects of differentiated music on cycling time trial. *International Journal of Sports Medicine*, *30*, 435–442. DOI: 10.1055/S-0028-1112140

Lucía, A., Rabadán, M., Hoyos, J., Hernández-Capilla, M., Pérez, M. San Juan, A. F., et al. (2006). Frequency of the VO_2max plateau phenomenon in world-class cyclists. *International Journal of Sports Medicine*, *27*, 984–992.

Mosley, T., Hills, N., Hilson, K., Muhammed, B., Nelson, C., & Maultsby, J. (2007). The Way I Are [Recorded by Timbaland & K. Hilson]. On *Shock Value* [CD]. Los Angeles: Interscope Records.

Nethery, V. M. (2002). Competition between internal and external sources of information during exercise: Influence on RPE and the impact of the exercise load. *Journal of Sports Medicine and Physical Fitness*, *42*, 172–178.

North, A. C., & Hargreaves, D. J. (1997). The musical milieu: Studies of listening in everyday life. *The Psychologist*, *10*, 309–312.

North, A. C. & Hargreaves, D. J. (2008). Music and taste. In A. C. North, & D. J. Hargreaves (Eds.), *The social and applied psychology of music* (pp. 75–142). Oxford, UK: Oxford University Press.

Payne, S., McCabe, D., Harding, A., Chowdhury, B., & Pritchard, R. (2006). Valerie [Recorded by M. Ronson & A. Winehouse]. On *Version* [CD]. London: Sony Music. (2007)

Rejeski, W. J. (1985). Perceived exertion: An active or passive process? *Journal of Sport Psychology*, *75*, 371–378.

Rendi, M., Szabo, A., & Szabó, T. (2008). Performance enhancement with music in rowing sprint. *The Sport Psychologist*, *22*, 175–182.

Schwartz, S. E., Fernhall, B., & Plowman, S. A. (1990). Effects of music on exercise performance. *Journal of Cardiopulmonary Rehabilitation*, *10,* 312–316.

Simpson, S. D., & Karageorghis, C. I. (2006) Effects of synchronous music on 400-metre sprint performance. *Journal of Sports Sciences*, *24*, 1095–1102.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (5th ed). Needham Heights, MA: Allyn and Bacon.

Tankian, S., & Malakian, D. (2001). Chop Suey [Recorded by System Of A Down]. On *Toxicity* [CD]. Los Angeles: American Recordings.

Tenenbaum, G. (2001). A social-cognitive perspective of perceived exertion and exertion tolerance. In R. N. Singer, H. Hausenblas, & C. Janelle (Eds.), *Handbook of sport psychology* (pp. 810–820). New York: Wiley & Sons.

Turner, A. (2007). Brianstorm [Recorded by Arctic Monkeys].On *Favourite Worst Nightmare* [CD]. London: Domino Recording Company.

Virtanen, V. (2000). Sandstorm [Recorded by Darude]. On *Sandstorm* [CD]. Helsinki, Finland: BMG Music Publishing.

Table 1.

Details of musical selections used during experimental trials

		Musical Genre	
Beats per minute range		Pop	Rock
95–100 (Slow)	Artist	Mark Ronson ft. Amy Winehouse	Oasis
	Track title	Valerie	Wonderwall
	Album	*Version*	*(What's the Story) Morning Glory*
	Credit	Sony BMG (2007)	Creation Records (1995)
115–120 (Medium)	Artist	Timbaland	System Of A Down
	Track title	Way I Are	Chop Suey
	Album	*Shock Value*	*Toxicity*
	Credit	Interscope Records (2007)	Sony BMG (2001)
135–140 (Fast)	Artist	Darude	Prodigy
	Track title	Sandstorm	Firestarter
	Album	*Before The Storm*	*The Fat Of The Land*
	Credit	Helsinki Records (2000)	XL Recordings (1996)
155–160 (Very fast)	Artist	Bomfunk MCs	Arctic Monkeys
	Track title	Freestyler	Brianstorm
	Album	*In Stereo*	*Favourite Worst Nightmare*
	Credit	Sony Music (2000)	Domino Recording Company (2007)

Table 2

Descriptive statistics for combined female and male music tempo preference scores across six exercise intensities

	Music tempi							
Exercise intensity	Slow		Medium		Fast		Very fast	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
40% HRRmax	6.43	1.95	7.50	1.37	7.25	1.27	6.93	1.68
50% HRRmax	5.82	2.06	7.25	1.04	7.18	1.28	6.61	1.66
60% HRRmax	5.86	2.07	7.54	1.14	7.82	0.82	7.04	1.45
70% HRRmax	5.36	2.01	7.00	1.12	7.61	1.17	7.32	1.49
80% HRRmax	5.21	2.38	7.43	1.14	7.86	1.18	7.50	1.77
90% HRRmax	4.57	2.25	7.07	1.54	7.68	1.22	7.50	1.43

Exercise intensity	*M*	*SD*
40% HRRmax	7.05	1.62
50% HRRmax	6.73	1.64
60% HRRmax	7.08	1.62
70% HRRmax	6.84	1.73
80% HRRmax	7.01	1.97
90% HRRmax	6.72	2.06

Music tempo	*M*	*SD*
Slow	5.59	2.18
Medium	7.32	1.23
Fast	7.57	1.18
Very fast	7.14	1.60

Gender	*M*	*SD*
Male	6.67	1.83
Female	7.14	1.66

Note. *M* = mean; *SD* = standard deviation; HRRmax = maximal heart rate reserve.

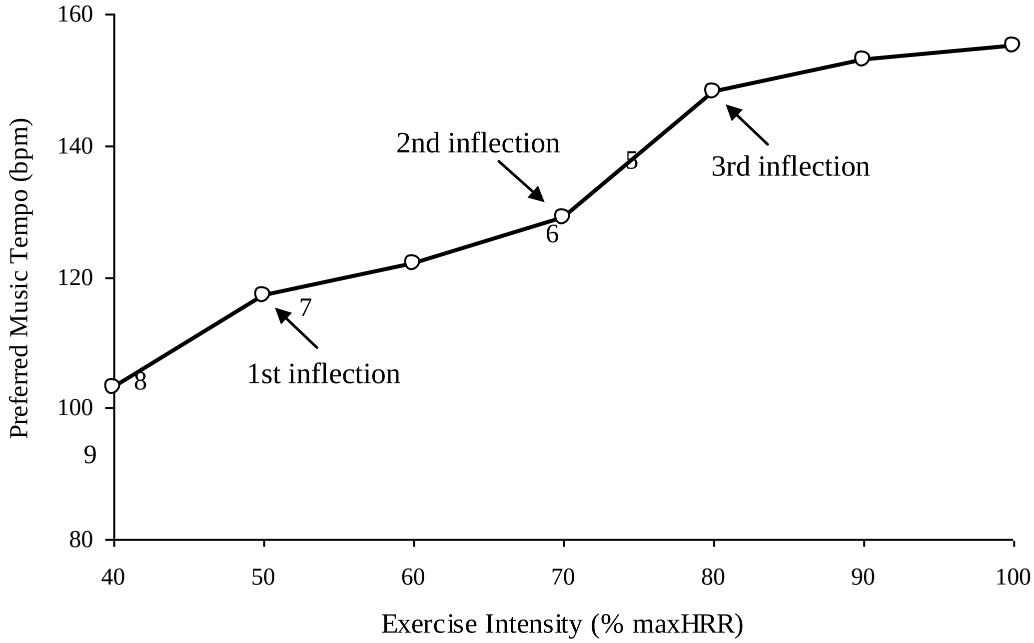

Figure 1. Hypothesized quartic relationship between exercise heart rate and preferred music tempo.

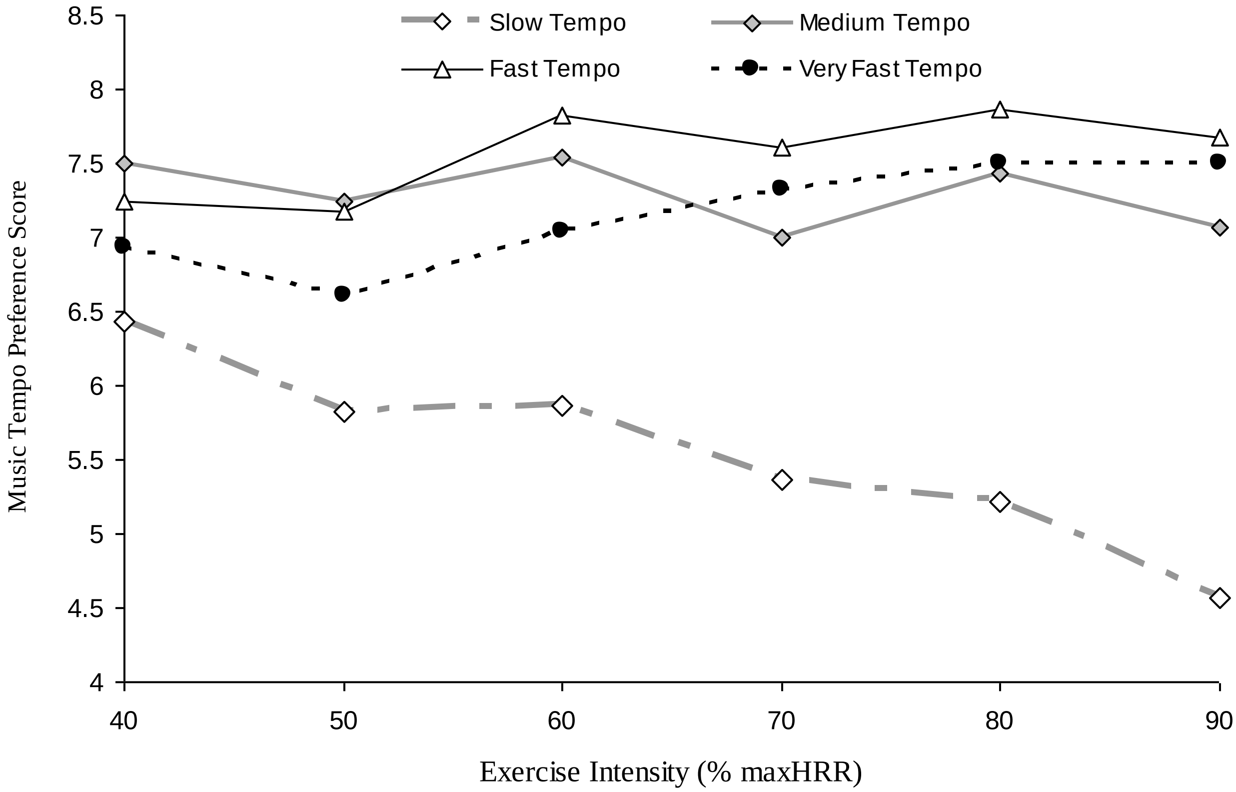

Figure 2. Significant two-way interaction for Exercise Intensity x Music Tempo ($p < .001$).

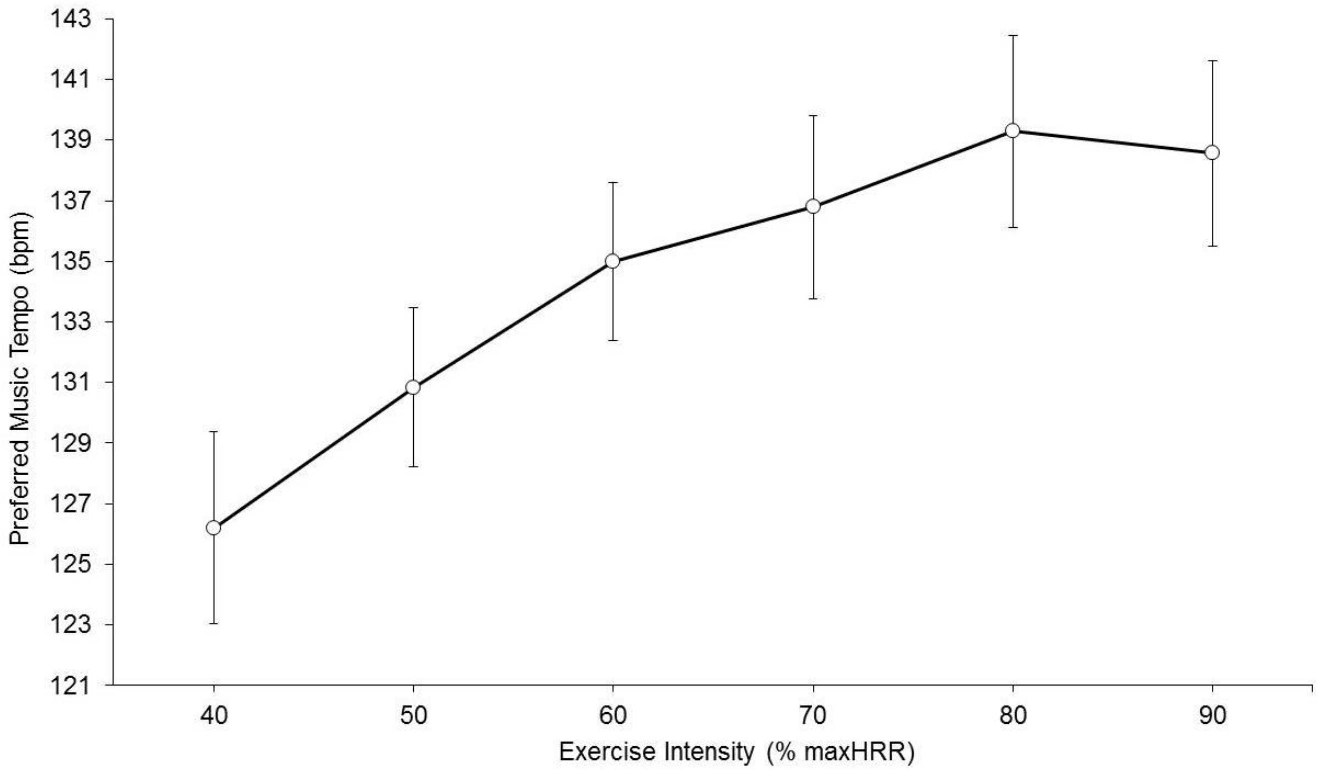

Figure 3. Observed relationship between exercise heart rate and music-tempo preference.