

Revisiting the relationship between exercise heart rate and music tempo preference.

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Published version

KARAGEORGHIS, C. I, JONES, Leighton, PRIEST, D. L, AKERS, R. I, CLARKE, A, PERRY, J and LIM, H. B. T (2011). Revisiting the relationship between exercise heart rate and music tempo preference. *Research Quarterly for Exercise and Sport*, 82 (2), 274-284.

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1 Running head: Heart rate music-tempo relationship

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3 Karageorghis, C. I., Jones, L., Priest, D. L., Akers, R. I., Clarke, A., Perry, J., & Lim, H. B. T.

4 (2011). Revisiting the exercise heart rate-music tempo preference relationship. *Research*

5 *Quarterly for Exercise and Sport*, 82, 274–284. doi: 10.1080/02701367.2011.10599755

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7 Revisiting the Exercise Heart Rate-Music Tempo Preference Relationship

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21 Final revision for publication submitted: 4 November 2009

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Abstract

1
2 In the present study, we investigated a hypothesized quartic relationship (meaning three inflection
3 points) between exercise heart rate (HR) and preferred music tempo. Initial theoretical
4 predictions suggested a positive linear relationship (Iwanaga, 1995a, 1995b); however, recent
5 experimental work has shown that as exercise HR increases, there may be step-changes and
6 plateaus that punctuate the profile of music tempo preference (Karageorghis, Jones, & Stuart,
7 2008). Tempi bands consisted of slow (95-100 bpm), medium (115–120 bpm), fast (135–140
8 bpm), and very fast (155–160 bpm) music. Twenty-eight active undergraduate students (mean
9 age = 20.6 years, $SD = 0.9$) cycled at exercise intensities representing 40, 50, 60, 70, 80, and 90%
10 of their maximal HR reserve while their music preference was assessed using a 10-point scale.
11 The Exercise Intensity x Music Tempo interaction was significant, $F(6.16, 160.05) = 7.08, p <$
12 $.001, \eta_p^2 = .21$, as was the test for a quartic trajectory in the exercise HR–preferred music tempo
13 relationship, $F(19, 648) = 10.56, p < .001$. Whereas slow tempo music was not preferred at any
14 exercise intensity, preference for fast tempo increased, relative to medium and very fast tempo
15 music as exercise intensity increased. The implications for the prescription of music in exercise
16 and physical activity contexts are discussed.

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

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Introduction

1
2 Numerous studies in the last decade have addressed the impact of music either as an
3 ergogenic aid or as a means by which to regulate affective responses to exercise (e.g., Edworthy
4 & Waring, 2006; Lim, Atkinson, Karageorghis, & Eubank, 2009; Rendi, Szabo, & Szabo, 2008).
5 Such work has been inspired by theoretical advances within the domain of exercise psychology
6 (Karageorghis, Terry, & Lane, 1999; Karageorghis & Terry, 2009) as well as a proliferation in
7 the use of personal listening devices such as the *iPod*TM, which facilitate the construction of
8 personal playlists. Due to its proposed influences on psychological responses during exercise and,
9 ultimately, exercise adherence, carefully selected music may positively affect public health and is
10 therefore an important area of study (Karageorghis, 2008; Schwartz, Fernhall, & Plowman,
11 1990).

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

1 With reference to the application of asynchronous music, which is the focus of the present
2 study, there has been ongoing debate among researchers and exercise professionals as to how
3 exercise heart rate should relate to the prescribed tempo or speed of a piece of music (Gfeller,
4 1988; Karageorghis, Jones, & Low, 2006; Karageorghis, Jones, & Stuart, 2008; LeBlanc, 1995).
5 Tempo, which is measured in beats per minute (bpm), is the musical quality that is easiest to
6 manipulate (other than intensity/volume). It is a major determinant of one's psychophysical and
7 aesthetic response to a piece of music (e.g., Bishop, Karageorghis, & Kinrade, 2009; Edworthy &
8 Waring, 2006).

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

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

1 examining the relationship between HR and music tempo preference in an exercise context
2 (Karageorghis, Jones et al., 2006; Karageorghis et al., 2008).

3 Karageorghis, Jones et al. (2006) examined the relationship between exercise HR and
4 preferred tempo. Participants reported their preference for slow (80 bpm), medium (120 bpm),
5 and fast (140 bpm) tempo music selections in each of three treadmill walking conditions at 40,
6 60, and 75% of maximal heart rate reserve (HRRmax). A significant and large main effect for
7 music tempo was found, wherein a general preference for fast and medium tempo music over
8 slow music was evident ($\eta_p^2 = .78$). An Exercise Intensity x Music Tempo interaction effect of a
9 moderate order was also observed ($\eta_p^2 = .09$), with participants reporting a preference for either
10 fast or medium tempo music during low and moderate exercise intensities, but fast tempo music
11 during high intensity exercise.

12 Karageorghis et al. (2008) extended this line of enquiry by administering entire music
13 programs, rather than single musical excerpts, to participants. The genesis of this study was an
14 earlier suggestion that, despite the reported preference for fast tempo music at high exercise
15 intensity, continued exposure to such music may result in negative psychological outcomes such
16 as boredom and irritation due to the lack of variety (Karageorghis, Jones et al., 2006).

17 Accordingly, Karageorghis et al. administered medium, fast, and mixed tempi conditions (tracks
18 arranged in the order medium-fast-fast-medium-fast-fast) in addition to a no-music control, while
19 participants walked on an inclined treadmill at 70% HRRmax. Dependent measures included
20 music preference ratings, three Intrinsic Motivation Subscales (interest-enjoyment, pressure-
21 tension, and effort-importance), and global flow. The mixed-tempi condition was expected to
22 yield the most positive motivation outcomes; however, this hypothesis was refuted as the medium
23 tempi condition yielded the most positive outcomes. The authors suggested the possibility of a
24 step change in preference between 70% and 75% HRRmax, at which point participants express a

1 greater preference for fast tempo music. This is also the point at which energy production
2 becomes more reliant on anaerobic as opposed to aerobic pathways. Accordingly, participants
3 become more acutely aware of physiological sensations (Rejeski, 1985; Tenenbaum, 2001).
4 Indeed, Ekkekakis, Hall, and Petruzello (2004) reported that when exercise intensity exceeded the
5 ventilatory threshold, there were curvilinear declines in pleasure.

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

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

1 10% intervals), as well as preference at rest. It was hoped that this approach would provide
2 insight as to the trajectory of the relationship and enable the research team to make more accurate
3 recommendations to practitioners working in the domain of exercise and sport. While the short
4 duration of the exercise bouts slightly limits the external validity of the present study, it does
5 facilitate a full examination of the research question. The major potential contribution of this
6 study is that it will enable exercise practitioners to better prescribe musical selections for
7 different exercise intensities and aid participants in self-selection. By understanding the
8 relationship between exercise HRate and music tempo preference, the beneficial effects of music
9 as a motivator, affect enhancer, and ergogenic aid may be harnessed more fully (Karageorghis et
10 al., 2008). A secondary aim was to explore whether the relationship was moderated by gender.

11 **Method**

12 *Stage 1: Music Selection*

13 *Participants and procedure.* A sample of 147 volunteer sport science undergraduates
14 from two universities in southeast England, UK (60 women and 87 men; M age = 19.3 years, SD
15 = 1.9) were used to identify a pool of possible musical selections for use in the experimental
16 protocol of Stage 2. The participants in each stage of this study provided written informed
17 consent and were similar in terms of age (18–22 years), ethnicity (Caucasian), and sociocultural
18 background (brought up in the UK; see Karageorghis & Terry, 1997).

19 Participants recorded their five favorite pieces of music for an exercise context in order of
20 perceived speed of each piece (from slowest to fastest); at least one of the selections had to be
21 from the *rock* idiom. Subsequently, the selections were classified into the *rock* and *pop* idioms (to
22 give experimental participants a choice) while other idioms were excluded. The 16 most
23 frequently recorded tracks in each idiom were subjected to further testing. Thus, four tracks were

1 used at each of four tempi: slow (95–100 bpm), medium (115–120 bpm), fast (135–140 bpm),
2 and very fast (155–160 bpm).

3 A panel of eight (2 women and 6 men, M age = 20.6 years, SD = 1.1) purposively selected
4 undergraduate sport sciences students from a university in south-east England, rated the
5 motivational qualities of 32 tracks (16 from each idiom with four from each tempo) using the
6 Brunel Music Rating Inventory-2 (BMRI-2: Karageorghis, Priest, et al., 2006). The tempo item
7 was omitted from the BMRI-2, as tempo formed an independent variable in the present design. A
8 90 s excerpt of each track was used to include at least one verse and chorus. The panel rated the
9 motivational qualities of each track with reference to a cycle ergometry task in accordance with
10 the instructions of Karageorghis, Priest et al. (2006). This procedure was undertaken to ensure
11 that, although the tempi between tracks differed, there would be homogeneity in terms of the
12 music's other motivational qualities of the music (e.g. melody, harmony, lyrical affirmations,
13 extra-musical associations) so that this factor did not present a threat to internal validity.

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

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

3 *Stage 2: Experimental Investigation*

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

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

16 *Apparatus and measures.* A cycle ergometer (Monark 874E; Monark Exercise AB,
17 Vansbro, Sweden) was used for testing along with a wall-mounted stereo system (Tascam CD-
18 A500; TEAC Corp., Tokyo, Japan) and a decibel meter (GA 102 Sound Level Meter Type 1;
19 Castle Associates, Scarborough, UK) to standardize music intensity at 75 dBA. This sound
20 pressure level (volume) would typify most exercise facilities but still lie within safe limits from
21 an audiological perspective. Target HR was assessed by use of a HR monitor attached to the
22 sternum of each participant and a sensor (Polar Accurex Plus; Polar Electro, Kempele, Finland)
23 held by one of the experimenters. Tempo preference at each of the six work intensities was

1 assessed using a single item developed by Karageorghis, Jones, et al. (2006) and further tested by
2 Karageorghis et al. (2008). The item was modified slightly to suit the present protocol in the
3 following manner: “Rate your preference for this track based on how you feel right now” (as
4 opposed to “based on the work level you have just experienced”) with responses provided on a
5 10-point scale anchored by 1 (*I do not like it at all*) and 10 (*I like it very much*). The term
6 “preference” used in the item can be interpreted as being synonymous with the degree of liking
7 for each track as was the case in the two preceding studies (Karageorghis, Jones, et al., 2006;
8 Karageorghis et al., 2008). For the baseline measurement at rest, the same item was administered
9 across both sets of experimental trials, thus ensuring equivalence between them. To prevent
10 participants from becoming aware of the precise purpose of the study, no reference was made to
11 tempo (i.e., “Rate your preference for the tempo of this track...”). The obviation of this clear
12 threat to internal validity and the careful control of other motivational qualities (excepting tempo)
13 was felt to sufficiently justify the practice of assaying generic music preference rather than tempo
14 preference.

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

1 research team to standardize work intensity across participants. In applying the formula, resting
2 HR was assessed when each participant arrived for the pretest, after they had sat quietly in a
3 comfortable chair for 5 min.

4 *Habituation trial.* Each participant was habituated to the cycle ergometry task so as to
5 familiarize them with the experimental task and reduce the possibility of practice effects (Harris,
6 2008, pp. 156–157). Weight was added to increase pedal resistance rather than requiring the
7 participant to increase their pedal rate. The rationale for this procedure was to prevent any
8 potential synchronization of pedal rate and music tempo (see e.g., Anshel & Marisi, 1978). A
9 music tempo of 150 bpm was avoided; because it could result in synchronization effect.
10 Participants spent ~20 min on the cycle ergometer during the habituation trial, during which time
11 the experimental protocol was explained. Thus, the experimenters met each participant on four
12 occasions: (a) for a pre-test to establish their maximal HR, (b) once for a habituation session, and
13 (c) twice for each segment of the experimental protocol (40, 60, and 80% maxHRR or 50, 70, and
14 90% HRRmax).

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

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

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

15 All musical selections included one verse and one chorus, and were of approximately 90 s
16 in duration. Participants maintained steady state for 30 s at the prescribed exercise intensity;
17 subsequently, they heard and responded to four 90-s musical excerpts with a 30-s period of
18 silence between each. In cases where the tracks deviated slightly from the required tempi (95-100
19 bpm, 115-120 bpm, 135-140 bpm, and 155-160 bpm), they were digitally altered during
20 recording to correspond with the required tempo. Previous work indicates that tempo changes of
21 ± 4 bpm are indiscernible among nonmusicians (Levitin & Cook, 1996). A decision was made to
22 include gaps of 15 bpm between the tempi ranges to render the musical selections clearly
23 discernible from each other in terms of tempo, and to facilitate comparison with similar past
24 research (Karageorghis, Jones, et al., 2006; Karageorghis et al., 2008).

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

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

16 *Data Analysis*

17 Data were screened for univariate outliers using z scores $> \pm 3.29$ and for multivariate
18 outliers using the Mahalanobis distance method with $p < .001$ (Tabachnick & Fidell, 2007, pp.
19 68–69). There was a single dependent variable, music tempo preference, and three independent
20 variables: exercise intensity (40, 50, 60, 70, 80, 90% HRRmax), music tempo (slow, medium,
21 fast, and very fast), and gender. Thus, after checks to ensure that the data were suitable for
22 parametric analysis, a mixed-model 6 x 4 x 2 (Gender x Exercise Intensity x Music Tempo)
23 ANOVA was applied to the preference data. In addition, a mixed-model (Time x Music Tempo)
24 ANOVA was used to check whether preferences differed at rest between the two experimental

1 trials. Following appropriate reconfiguration of the data, a significance value ($p < .05$) relating to
2 a quartic relationship was examined using an independent samples one-way ANOVA.

3 **Results**

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

12 Mauchly's test indicated a violation of the sphericity assumption for the Intensity x Music
13 Tempo interaction, Mauchly's $W = .00$, $\epsilon = .41$, $p < .001$, the intensity main effect, Mauchly's W
14 $= .09$, $\epsilon = .49$, $p < .001$, and the tempo main effect, Mauchly's $W = .29$, $\epsilon = .58$, $p < .001$.

15 Greenhouse-Geisser adjustments were applied accordingly. Collectively, the diagnostic tests
16 indicated that the assumptions underlying a two- and three-way mixed-model ANOVA were
17 satisfactorily met. The test of music preference at rest between the two experimental trials
18 confirmed that there were no significant differences, $F(3, 25) = .33$, $p = .345$, $\eta_p^2 = .04$.

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

24

1 *Interaction Effects*

2 The higher-order interaction of Gender x Exercise Intensity x Music Tempo was
 3 nonsignificant, $F(15, 12) = .68, p = .802, \eta_p^2 = .03$, as were the two-way interactions of Gender
 4 x Exercise Intensity, $F(2.47, 160.05) = .50, p = .646 \eta_p^2 = .02$, and Gender x Music Tempo, $F(3,$
 5 $390) = 1.99, p > .05, \eta_p^2 = .123$. The two-way interaction of Exercise Intensity x Music Tempo
 6 was significant (see Figure 2), $F(6.16, 160.05) = 7.08, p < .001, \eta_p^2 = .21$, and accounted for
 7 21% of the variance in music tempo preference. This interaction was also associated with a
 8 significant linear $F(22, 648) = 9.37, p < .001$, quadratic $F(21, 648) = 9.74, p < .001$, cubic $F(20,$
 9 $648) = 10.15, p < .001$, and quartic trajectory $F(19, 648) = 10.56, p < .001$. The quartic
 10 relationship (see Figure 3) was only marginally stronger than the cubic relationship (two points of
 11 inflection), while the same applies in comparing the quadratic against the cubic relationship.

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

1 *Main Effects*

2 The main effects indicated no significant differences in exercise intensity, $F(2.47, 64.28)$
3 $= 2.43, p = .084, \eta_p^2 = .08$, or sex, $F(1, 26) = 2.43, p = .131, \eta_p^2 = .09$. There was however a
4 significant main effect for music tempo, $F(1.73, 44.96) = 15.56, p < .001, \eta_p^2 = .37$, which
5 accounted for 37% of the variance in music preference. Pairwise comparisons indicated that the
6 slow tempo music was least preferred when compared to medium, 95% C.I. = -2.60 to -.88, $p <$
7 $.001$, fast, 95% C.I. = -3.13 to -.84, $p < .001$, and very fast tempo music, 95% C.I. = -2.80 to -.31,
8 $p = .009$ (see Table 2).

9 **Discussion**

10 The primary aim of the present study was to test the hypothesized quartic relationship
11 between exercise HR and music tempo preference, while a secondary aim was to explore whether
12 the relationship was moderated by gender. The strong main effect for music tempo ($\eta_p^2 = .37$)
13 demonstrates that this musical quality plays an important role in determining music preference
14 during exercise. This result is in concert with theoretical predictions regarding the nature of the
15 physiological arousal-music tempo relationship (e.g., Iwanaga, 1995a, North & Hargreaves,
16 2008, pp. 270, 294). As hypothesized, there was a quartic relationship ($p < .001$) between
17 exercise HR and music tempo preference, although it is noteworthy that the test for a cubic
18 relationship was equally significant ($p < .001$). Gender had no moderating influence on the
19 relationship, which mirrors the findings of recent studies (Karageorghis, Jones, et al., 2006;
20 Karageorghis et al., 2008).

21 With reference to the significant Exercise Intensity x Music Tempo interaction, the slow
22 tempo music was inappropriate at all exercise intensities while the very fast tempo music elicited
23 relatively lower music preference ratings at the low intensities; these findings mirror those of

1 similar studies (e.g., Karageorghis, Jones, et al., 2006; Karageorghis et al., 2008). At the mid-
2 range intensities of 50–60% HRRmax, the observed differences in music preference between the
3 medium and fast tempi conditions were similar to those reported by Karageorghis, Jones, et al., in
4 that fast tempo music was preferred.

5 At lower exercise intensities, the relationship between exercise HR and music tempo
6 preference was positive and linear (see Figure 3). As exercise intensity increased, the first
7 instance of nonlinearity is an inflection point at 60% HRRmax (see Figure 3). This is consistent
8 with the results reported by Karageorghis, Jones, et al. (2006) and can be explained by the fact
9 that the majority of up-tempo pop, rock, and dance music falls into a band of 115–140 bpm.
10 Karageorghis et al. (2008) suggested that there might be a “step change” in preference between
11 70% and 75% HRRmax, which is close toward the level of intensity typically associated with the
12 ventilatory or lactate threshold; after this point there is a closer relationship between
13 physiological variables and rating of perceived exertion (Ekkekakis et al., 2004; Rejeski, 1985;
14 Tenenbaum, 2001). The present findings do indicate a step change, albeit far less pronounced
15 than that which was hypothesized (see Figure 3).

16 The third inflection point in the relationship between exercise HR and music tempo
17 preference is caused by attenuation in music tempo preference at higher exercise intensities (i.e.,
18 > 80% HRRmax). Owing to the normal distribution of music tempi, relatively few pieces are
19 recorded at the highest end of the tempi spectrum. Such faster pieces may contain too much
20 information for the limited attentional capacity of the afferent nervous system (see Rejeski, 1985;
21 Tenenbaum, 2001) or an arousal potential that is too great for the listener, even if they are in a
22 state of heightened excitement (Berlyne, 1971). These psychobiological factors may be
23 compounded by the expectancy that music typically falls within a certain range of tempi (North
24 & Hargreaves, 1997). Accordingly, extremely fast pieces, as well as being too complex and over-

1 arousing may also be unfamiliar; a factor that is thought to strongly determine music preference
2 (Berlyne; Karageorghis et al., 1999). The concomitant influence of such factors may explain the
3 attenuation in music-tempo preference at higher exercise intensities; once relatively high exercise
4 intensity is reached (i.e., > 80% HRRmax), an increase in music tempo will not result in
5 corresponding increases in preference ratings.

6 The aesthetic response to musical tempo during exercise appears to be similar for both
7 sexes. What the present findings do not reveal is whether women and men respond differently to
8 the more complex rhythmical features within music. Whereas tempo is an index of speed,
9 rhythmical patterns might be responded to differently according to gender; indeed, women are
10 socialized to develop a greater interest in dance and have been shown to exhibit a stronger
11 preference, compared to men, for the rhythmical constituents of music (see Karageorghis et al.,
12 1999).

13 The trajectory of the relationship between exercise intensity and music tempo preference
14 depicted in Figure 3 (using recognized configured data) approximates the hypothesized quartic
15 relationship predicted (see Figure 1); however, the trend is more akin to a cubic relationship. We
16 suggest that explaining it as such to practitioners is preferred owing to the relative simplicity of a
17 cubic trajectory (i.e., “there is a linear rise in preferred music tempo across low-to-moderate
18 exercise intensities, a leveling out at moderate-to-high intensities, and then a slight dip at 80%
19 HRRmax”). The stabilization of music tempo preference that followed the first inflection point
20 occurred at a higher exercise intensity than predicted (Karageorghis & Terry, 2009). This means
21 that a positive linear relationship spanned a greater range of submaximal exercise intensities than
22 was forecast. Furthermore, the stabilization itself (represented by the first plateau in the line; see
23 Figure 3) applied to a much smaller range of exercise intensities than projected. This stabilization
24 at moderate exercise intensities (60–70% HRRmax) may have occurred because certain

1 participants did not wish to work at a very high intensity (cf. Ekkekakis et al., 2004). Hence, in
2 an attempt to maintain or slightly reduce workload, they expressed a preference for music of
3 medium tempo.

4 The step change in music tempo preference occurs, as predicted, at around 70–75%
5 HRRmax, but it was less pronounced than expected, indicating a resumption of the positive linear
6 relationship that was found at lower exercise intensities. The attenuation which occurs after the
7 third inflection point is even more pronounced than the estimate (see Figure 1). As with the first
8 plateau, this tendency may reflect participants' desire to exercise at a lower intensity level. It may
9 also reflect the automatic attentional switching that takes place during high intensity exercise
10 which severely limits participants' ability to focus on external stimuli such as music (Rejeski,
11 1985; Tenenbaum, 2001). Despite the statistical significance of the quartic and cubic trajectories
12 ($p < .001$), the visualization depicted in Figure 3 ostensibly displays a cubic relationship. As
13 alluded to earlier, this “ceiling effect” evident at very high exercise intensities should inform
14 music-related interventions, whereas promotion of a quartic trajectory in selecting music tempi
15 may represent an over-complication.

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

23

24

1 *Limitations of the Present Study*

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

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

21 **Conclusions and Recommendations**

22 Taken collectively, the present findings underline the importance of exercise intensity in
23 determining music tempo preference during exercise. The findings indicate that, while the
24 relationship between exercise HR and music-tempo preference has linear aspects as predicted

1 both by theorists (Iwanaga, 1995a, 1995b) and exercise practitioners (Gfeller, 1988), it is
2 punctuated by nonlinear features as theorized by Karageorghis et al. (2008) and Karageorghis and
3 Terry (2009). The quartic relationship that was found might be explained by recourse to
4 psychomusicological (e.g., North & Hargreaves, 1997), psychobiological (e.g., Berlyne, 1971),
5 and information processing (e.g., Rejeski, 1985; Tenenbaum, 2001) factors.

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

22 When compared to previous findings (e.g., Karageorghis, Jones, et al., 2006;
23 Karageorghis et al., 2008), the present findings have greater utility for those prescribing
24 asynchronous music for exercise. For optimal effect, practitioners should aim to employ a narrow

1 band of musical tempi (125–140 bpm) when working with those exercising in the low-to-
2 moderate range of exercise intensities (40–70% HRRmax). Slower tempi (< 100 bpm) do not
3 appear to be appropriate for any exercise intensity. Practitioners should be mindful of the plateau
4 in the exercise HR–tempo preference relationship, which occurs above 70–75% HRRmax.
5 Beyond this intensity, the tempo should either be maintained or reduced slightly in accordance
6 with the quartic trajectory. For those advising practitioners, we suggest that because the practical
7 difference between the significant quartic and cubic relationships is negligible, the exercise HR–
8 tempo preference relationship should be presented as being cubic in nature (two inflection
9 points), with a linear progression in the early stages (125–135 bpm), followed by a leveling of the
10 trend line from 60 to 80% HRRmax (135–140 bpm), then a plateau or “ceiling effect” beyond
11 80% HRRmax (see Figure 3). The present results indicate that fast tempi are most preferred
12 during high intensity exercise although future work might explore whether at the point at which
13 the body is shouting “stop”, silence is indeed “golden”.

14

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1 **Table 1.**

2 Details of musical selections used during experimental trials

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

3

4

1 **Table 2**

2

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

4

Exercise intensity	Music tempi							
	Slow		Medium		Fast		Very fast	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
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	<i>M</i>	<i>SD</i>	Music tempo	Gender		<i>M</i>	<i>SD</i>
				Male	Female		
40% HRRmax	7.05	1.62	Slow	5.59	2.18	6.67	1.83
50% HRRmax	6.73	1.64	Medium	7.32	1.23	7.14	1.66
60% HRRmax	7.08	1.62	Fast	7.57	1.18		
70% HRRmax	6.84	1.73	Very fast	7.14	1.60		
80% HRRmax	7.01	1.97					
90% HRRmax	6.72	2.06					

5

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

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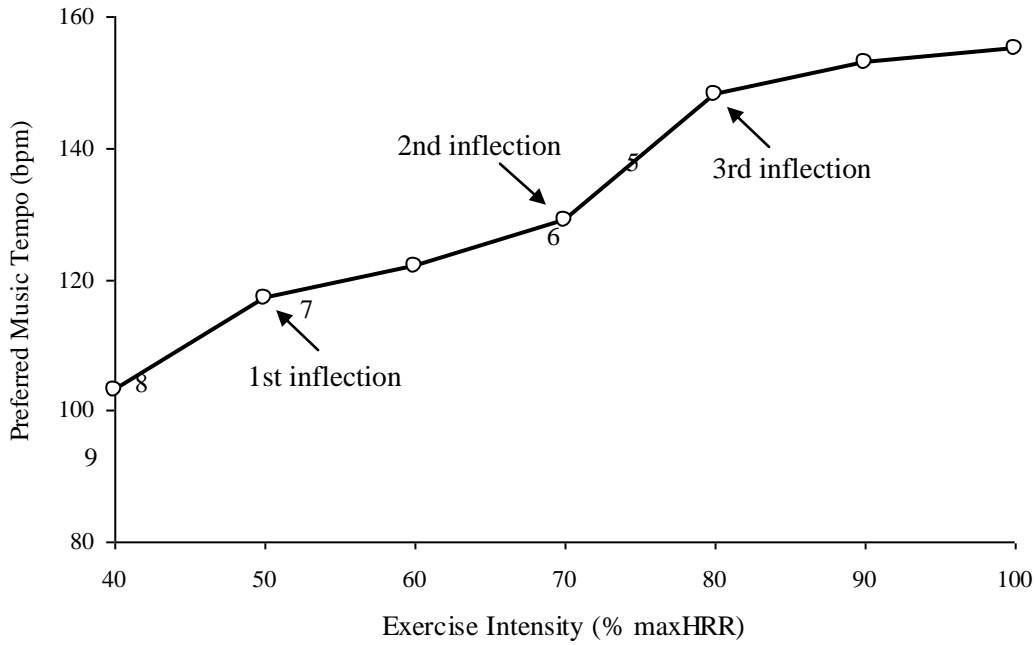
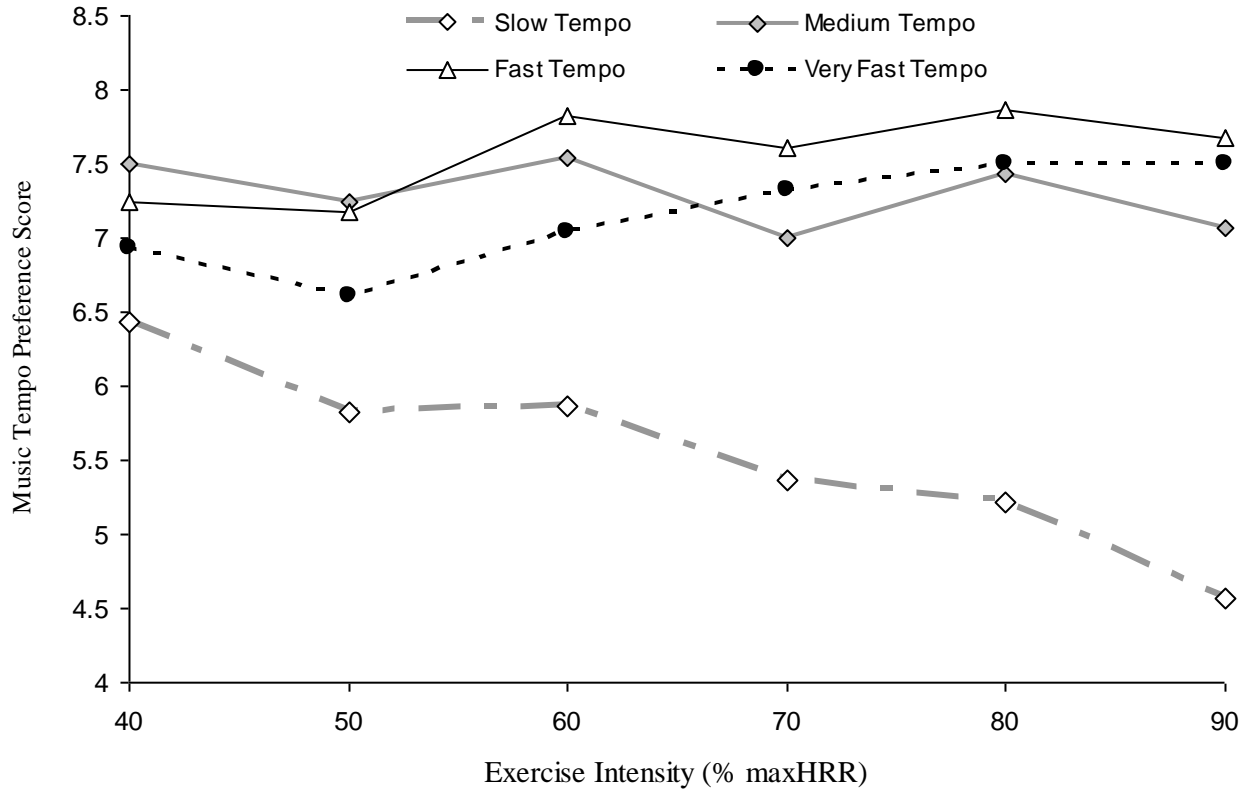


Figure 1. Hypothesized quartic relationship between exercise heart rate and preferred music tempo.

1



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

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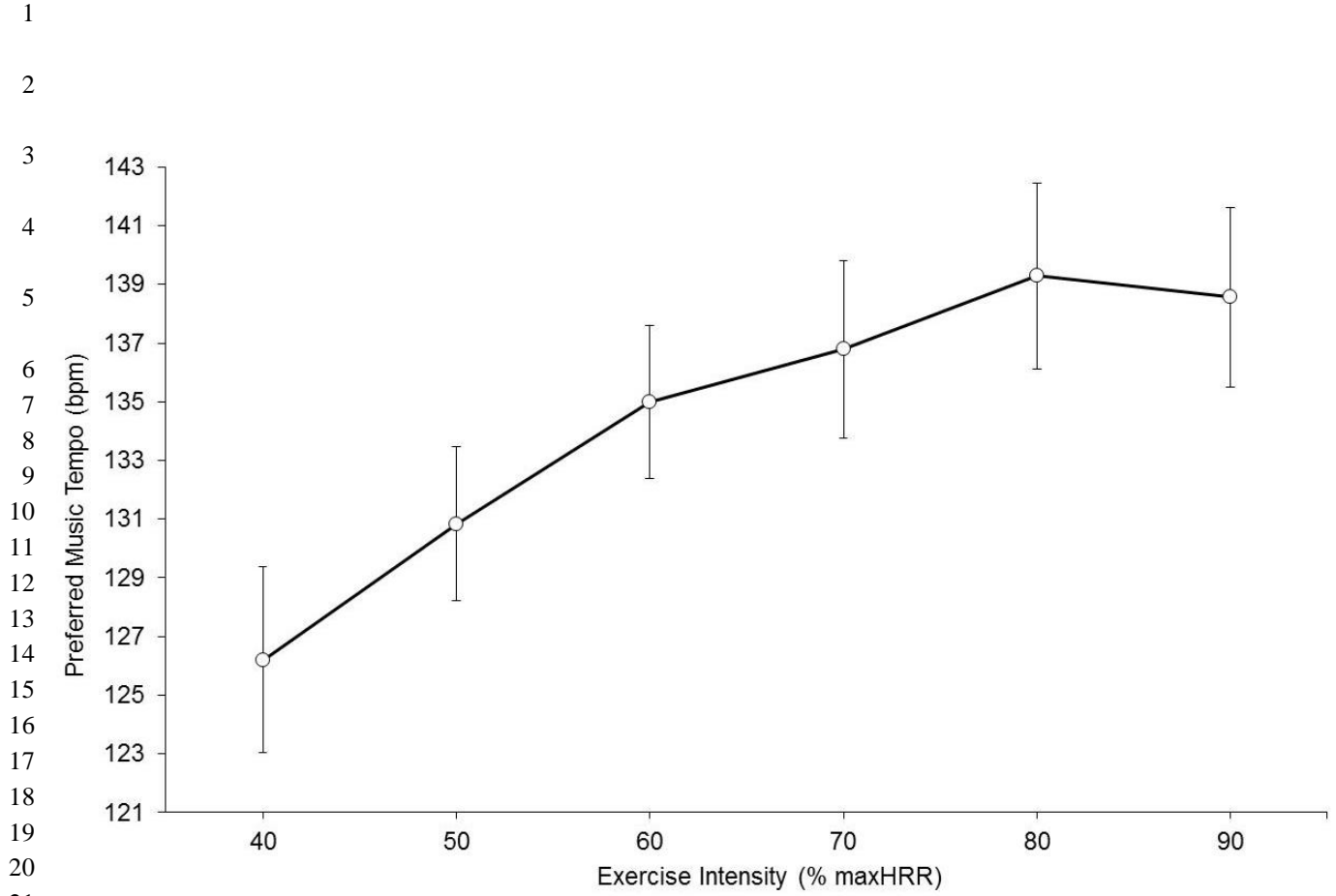
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22 **Figure 3.** Observed relationship between exercise heart rate and music-tempo preference.