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7   **Psychophysiological effects of music on acute recovery from high-intensity interval training**

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10   Leighton Jones[1], Nicholas B. Tiller[1], Costas I. Karageorghis[2]

11   [1]Academy of Sport and Physical Activity, Sheffield Hallam University, UK

12   [2]Department of Life Sciences, Brunel University London, UK

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23   Dr Nicholas B. Tiller, Sheffield Hallam University, Faculty of Health and Wellbeing, Collegiate Hall,
24   Collegiate Crescent, Sheffield S10 2BP, England, UK.
25   Tel: +44 (0)114 225 5962, Email: n.tiller@shu.ac.uk
26
27
28   Dr Costas I. Karageorghis, Department of Life Sciences, Brunel University London, Uxbridge,
29   Middlesex UB8 3PH, England, UK
30   Tel: + 44 (0)1895 266 476, Fax: + 44 (0)1895 269 769, Email: costas.karageorghis@brunel.ac.uk
31
32
33   Correspondence concerning this article should be sent to:
34   Dr Leighton Jones, Sheffield Hallam University, Faculty of Health and Wellbeing, Collegiate Hall,
35   Collegiate Crescent, Sheffield S10 2BP, England, UK.
36   Tel: +44 (0)114 225 5590, Email: leighton.jones@shu.ac.uk
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1   Running head: Effects of music on acute recovery from HIIT

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1   **Abstract**

2   Numerous studies have examined the multifarious effects of music applied during exercise but few

3   have assessed the efficacy of music as an aid to recovery. Music might facilitate physiological

4   recovery via the entrainment of respiratory rhythms with music tempo. High-intensity exercise

5   training is not typically associated with positive affective responses, and methods of assuaging this

6   warrant further exploration. This study assessed the psychophysiological effects of music on acute

7   recovery and prevalence of entrainment in between bouts of high-intensity exercise. Thirteen male

8   runners (M_{age} = 20.2 ± 1.9 years; BMI = 21.7 ± 1.7; $\dot{V}O_2$ max = 61.6 ± 6.1 ml·kg·min^{-1}) completed

9   three exercise sessions comprising 5 x 5-min bouts of high-intensity intervals interspersed with a 3-

10   min passive recovery period. During recovery, participants were administered positively-valenced

11   music of a slow-tempo (55–65 bpm), fast-tempo (125–135 bpm), or a no-music control. A range of

12   measures including affective responses, RPE, cardiorespiratory indices (gas exchange and pulmonary

13   ventilation), and music tempo-respiratory entrainment were recorded during exercise and recovery.

14   Fast-tempo, positively-valenced music resulted in higher Feeling Scale scores throughout recovery

15   periods ($p < 0.01$, $\eta_p^2 = 0.38$). There were significant differences in HR during initial recovery periods

16   ($p < 0.05$, $\eta_p^2 = 0.16$), but no other music-moderated differences in cardiorespiratory responses. In

17   conclusion, fast-tempo, positively-valenced music applied during recovery periods engenders a more

18   pleasant experience. However, there is limited evidence that music expedites cardiorespiratory

19   recovery in between bouts of high-intensity exercise. These findings have implications for athletic

20   training strategies and individuals seeking to make high-intensity exercise sessions more pleasant.

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22   *Keywords:* Affect; Entrainment; Exercise; HIIT; Tempo

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1   **1. Introduction**

2   A large body of literature has sought to delineate the ergogenic, psychological, and

3   psychophysical effects of music when applied pre-task or as an in-task accompaniment to exercise

4   (e.g., Eliakim et al., 2007; Hutchinson et al., 2011; Karageorghis & Jones, 2014). There is a paucity of

5   literature concerning the application of music as a post-task or recuperative aid, and further

6   exploration is required to elucidate its potential psychological and physiological benefits (Terry &

7   Karageorghis, 2011; Yamasaki et al., 2012). Among the few researchers who have assessed the

8   efficacy of music as a recuperative aid to exercise, Jing and Xudong (2008) explored the effects of

9   sedative music on passive recovery from a 15-min exhaustive cycle ergometer trial. In this instance,

10 sedative music led to decreases in heart rate (HR) intimating the capacity for sedative music to

11 expedite recovery from exercise. Contrastingly, applying motivational music post-exercise encourages

12 participants to engage in a more active recovery which, in turn, leads to reduced blood lactate

13 concentrations (Eliakim et al., 2012).

14   The emotional quality of music is a salient factor in promoting acute recovery from a stressor

15 and is a noteworthy consideration (see Karageorghis, 2016). Positively-valenced music that induces

16 low-levels of arousal has been shown to promote more effective physiological and subjective recovery

17 from psychological stress (Sandstrom, 2010). The tempo of a piece of music is a determinant of its

18 emotional qualities, with fast-tempo music consistently associated with states characterized by high-

19 arousal and positive affective valence (e.g., Dalla Bella, Peretz, Rousseau, & Gosselin, 2001). Tempo

20 has also been shown to be one of the strongest correlates of physiological responses to music, with

21 fast-tempo music inducing higher breathing and heart rates (Gomez & Danuser, 2007). There is a

22 corpus of literature addressing the capacity of music to regulate emotions and, predominantly, humans

23 respond with positive emotions such as happiness and elation when listening to music (e.g., Juslin,

24 Liljestrom, Vastfjall, Barradas, & Silva, 2008). The findings of Juslin et al. (2008) indicate that

25 humans typically use music to promote positive emotional states, and the propensity for music to elicit

26 such positive states can be harnessed during exercise (Karageorghis, 2017).

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1   **1.1 Exercise Intensity**

2   Interval exercise has long been a staple of athletic training programs, and high-intensity

3   interval training (HIIT) is becoming increasingly popular among recreationally-active people owing to

4   its cardiovascular and metabolic benefits (e.g., Little et al., 2010). Sedative music might have a role to

5   play in facilitating cardiorespiratory recovery from high-intensity, intermittent exercise via several

6   neurogenic pathways. Animal models suggest that auditory stimulation with classical music directly

7   influences the autonomic nervous system via the gastric vagal nerve, resulting in elevated

8   parasympathetic function (Nakamura et al., 2009). Similarly, humans listening to relaxing music

9   exhibit increased parasympathetic drive, as assessed via heart rate variability (Perez-Lloret et al.,

10   2014). Although not yet studied extensively in exercising individuals, auditory stimuli has been shown

11   to increase parasympathetic drive, leading to reductions in HR, respiration rate, and blood pressure, all

12   of which are key markers of cardiorespiratory recovery. It is possible that musical selections

13   characterized by a slow tempo may elicit similar responses in athletic populations.

14   In addition to physiological responses to high-intensity exercise, there is evidence to suggest

15   that incremental exercise from low-to-severe intensities causes in-task affective responses to shift from

16   a neutral or positive valence toward a negative valence (e.g., Smith et al., 2015). This shift was

17   conceptualized in the dual-mode model of exercise-related affect (Ekkekakis, 2003) and is a

18   consequence of the continuous interplay between cognitive processes and interoceptive cues (see e.g.,

19   Acevedo & Ekkekakis, 2006, pp. 96–104). Although affective valence typically returns to pre-exercise

20   levels following vigorous activity (the so-called "affective rebound"; Ekkekakis, Hall, & Petruzzello,

21   2008), this phenomenon requires further examination in relation to HIIT, which is characterized by

22   repetitive exercise and multiple rest periods. High-intensity exercise sessions pose a challenge

23   regarding how the decline in affect might be assuaged. Given the increased adoption of HIIT by the

24   general population and that a lack of enjoyment is often cited as a barrier to exercise adherence

25   (Salmon et al., 2003), the affective responses to such exercise are a salient public health issue. There is

26   evidence to support the ergogenic and affect-enhancing benefits of self-selected music across the

27   entire course (during exercise and recovery periods) of a high-intensity interval training session (Stork

28   et al., 2015). Self-selected music, however, is generally unsuitable for studies that seek to examine

1   responses to specific qualities of music (e.g., tempo) owing to the wide variety of music that

2   participants will invariably select (see e.g., Hallett & Lamont, 2016). Moreover, the psycho-acoustic

3   qualities of music tracks vary greatly, which means that a nonstandardized approach poses a threat to

4   the internal validity of studies that examine the mechanisms underlying the efficacy of music.

5   **1.2 Potential Underlying Mechanisms**

6   The bio-musicological principle of entrainment pertains to a mechanism that underlies the

7   influence of music on physiological responses. Entrainment theory (Thaut, 2008, pp. 39-59) seeks to

8   explain how music influences the body's main pulses such as brainwaves, HR, and respiratory rate

9   (e.g., Khalfa et al., 2008), and has been attributed, at least in part, to a central "pattern generator" or

10 pacemaker in the brain that serves to regulate temporal functioning (e.g., Schneider et al., 2010). In 12

11 participants, Haas et al. (1986) observed tight entrainment between music rhythm and respiratory duty

12 cycle (inspiration to expiration time), which was reinforced by rhythmic foot tapping. Furthermore,

13 Bernadi et al. (2005) reported a linear relationship between music tempi (ranging from 55–150 b$\cdot$min^{-1})

14 and two respiration indices (frequency and minute ventilation). This is of particular relevance to post-

15 exercise recovery given that manipulation of breath movement resulting in an extension of respiratory

16 duty cycle (via deep, slow breathing) has been shown to lower blood pressure and peripheral

17 sympathetic nerve activity (Oneda, Ortega, Gusmao, Arauio, & Mion, 2010). Accordingly, it is

18 plausible that a music-modulated lowering of respiratory rate via the biomusicological principle of

19 entrainment might facilitate cardiorespiratory recovery from strenuous exercise. Of the components

20 that constitute a musical work, it is suggested that tempo is the most salient in promoting entrainment

21 (Khalfa et al., 2008; Thaut, 2008), and further exploration is required to examine the possible role of

22 this constituent of music in promoting post-exercise recovery.

23 The entrainment research conducted to date has focused predominantly upon resting

24 participants. If such entrainment between bodily rhythms and music can be replicated during the

25 recovery periods of high-intensity exercise, there could be a beneficial influence on the recovery of

26 cardiorespiratory variables by lowering respiratory frequency, and thus HR, to a rate that is determined

27 by the musical beat. This would, in turn, enhance exercise capacity by increasing cardiac reserve for

1 subsequent efforts. Similarly, it may be that starting high-intensity intervals from an enhanced

2 affective state limits the degree of displeasure experienced.

3 **1.3 Study Aims**

4 Despite a logical premise and plausible mechanistic foundation, few studies have assessed the

5 influence of music on acute psychological and cardiorespiratory recovery in between bouts of high-

6 intensity exercise. This study seeks to complement the contemporary theoretical models addressing the

7 use of music in exercise (e.g., Karageorghis, 2016), as well as inform athletic training programs. It was

8 hypothesized that slow-tempo, positively-valenced music applied in between bouts of high-intensity

9 exercise would promote a more positive psychological state and facilitate acute cardiorespiratory

10 recovery when compared to fast-tempo, positively-valenced music and a no-music control.

11 **2. Method**

12 **2.1. Stage 1: Music Selection**

13 Twenty four music tracks were initially selected by the experimenters based on the tempo

14 ranges required to address the research question (12 slow-tempo: 55–65 bpm; 12 fast-tempo: 125–135

15 bpm). Tracks included in this selection had readily discernible beats that matched the published tempo.

16 Owing to difficulty in identifying suitable tracks in the range of 55-65 bpm, those at a tempo of ± 3

17 bpm were considered and digitally altered if appropriate. Previous empirical work indicates that tempo

18 changes of ± 4 bpm are indiscernible among nonmusicians (Levitin & Cook, 1996).

19 Eight participants (M_{age} = 25.2 ± 3.6 years) rated the 24 music tracks (3 min excerpts) with the

20 aim of identifying those suitable for use in the experimental protocol (Stage 2). Participants at each

21 stage of the study were similar in terms of age (18–30 years), and socio-cultural background (had

22 spent their formative years in the UK). Participants who reported any form of hearing deficiency or

23 congenital amusia (i.e., tone-deafness) were excluded. The 24 musical excerpts were rated using the

24 Affect Grid (Russell et al., 1989), providing two scores in line with each of its two dimensions:

25 pleasure–displeasure and low arousal–high arousal. Five slow-tempo tracks that were rated in the

26 bottom-right quadrant of the Affect Grid (i.e., "pleasant low-arousal"), and within one whole unit of

27 each other in terms of affective valence and arousal scores, were selected for use in the experimental

28 trials (see Table 1). Five fast-tempo tracks that were rated in the upper-right quadrant of the Affect

1   Grid (i.e., "pleasant high-arousal") and within one whole unit of each other were selected for use in

2   Stage 2 (see Table 1). The affective valence (pleasure–displeasure) ratings of the slow- and fast-tempo

3   tracks were within one whole unit of each other, and the arousal scores for the fast-tempo tracks were

4   ~4 units higher than those for the slow-tempo tracks.

5   **2.2. Stage 2: Experimental Investigation**

6   **2.2.1. Power analysis.** To establish appropriate sample size, a power analysis was undertaken

7   using the software G*Power3 (Faul et al., 2007). Based on a more conservative effect size than that of

8   Stork et al. (2015; $\eta_p^2 = 0.06$), an alpha level of 0.05, and power at .8 to protect beta at four times the

9   level of alpha (Cohen, 1988, pp. 4–6), the analysis indicated that 12 participants would be required to

10   detect effects on affective responses (Feeling Scale).

11   **2.2.2. Participants.** Twenty well-trained, male middle-distance runners were initially

12   recruited for the experimental investigation, however, seven of these failed to complete all sessions

13   owing to injury, competitive commitments, or inability to sustain the required work rate. Therefore, 13

14   participants completed all experimental conditions ($M_{age} = 20.2 \pm 1.9$ years; BMI = 21.7 ± 1.7).

15   Experimental procedures were approved by the Sheffield Hallam University Research Ethics

16   Committee and participants provided written informed consent. Participants were asked to abstain

17   from exercise for 24 h, alcohol and caffeine for 12 h, and food for 3 h prior to each visit. Participants

18   were similar in terms of training status and maximal aerobic capacity (see Table 2).

19   **2.2.3. Apparatus and measures.** Participants exercised on a treadmill (HP Cosmos Saturn)

20   while cardiorespiratory data were collected on a breath-by-breath basis using an online gas analyzer

21   (Oxycon Pro), and HR monitored via telemetry (Vantage NV). Music was played from a laptop

22   computer connected to over-ear headphones (Sennheiser HD201) at a standardized sound intensity (75

23   dBA). Pre- and post-exercise blood samples were collected into a 10 µl capillary tube and

24   subsequently analyzed for blood lactate concentration (Biosen). Rating of perceived exertion (RPE)

25   was recorded using the Borg CR10 scale (Borg, 1998). Affective valence and arousal were assessed

26   using the Feeling Scale (FS; Hardy & Rejeski, 1989) and the Felt Arousal Scale (FAS; Svebak &

27   Murgatroyd, 1985), respectively. Van Landuyt et al. (2000) found the FS to be correlated (0.51–0.88)

1   with the valence scale of the Self-Assessment Manikin and with the Affect Grid (0.41–0.59).

2   Ekkekakis (2013) suggested that the tandem use of the FS and FAS strengthened the discriminant

3   validity of the scales.

4   **2.2.4. Tempo-respiratory entrainment.** Music tempo and respiratory rhythms were

5   considered to be matched when the instantaneous ratio of tempo to mean respiratory frequency,

6   recorded at 15 s intervals, was within ± 0.05 of a whole- or half-integer value (see Paterson et al.,

7   1986). The prevalence of tempo-respiratory entrainment (ENT%) was calculated as the percentage of

8   the sampled data within each 3-min recovery period that met these criteria. The first and last 15 s of

9   each 3-min block were excluded from the analysis to account for the stabilization of respiratory

10   pattern and the recording of perceptual responses, respectively.

11   **2.2.5. Maximal exercise test and habituation.** Participants completed a maximal ramp

12   incremental exercise test on a motorized treadmill. Exercise commenced at 10 km·hr^{-1} for 4 min at a

13   1% incline (warm-up) after which the speed was increased by 1 km·hr^{-1} each minute until volitional

14   fatigue was reached. The test was designed to elicit maximal capacities within 8–12 min. Gas

15   exchange and HR were assessed continuously. Maximal aerobic capacity was deemed to have been

16   reached following the attainment of a single primary (plateau in oxygen uptake following an increase

17   in exercise intensity) or two secondary criteria (final RER $\geq$ 1.15, and HR within 10 bpm of age-

18   predicted maximum) in accord with BASES Guidelines (Winter et al., 2006). Following the test, gas

19   exchange threshold (GET) was identified using multiple parallel methods (Wasserman, 1984).

20   Subsequent to the maximal exercise test, participants were familiarized with the experimental protocol

21   and measures.

22   **2.2.6. Experimental protocol.** Participants completed three exercise sessions separated by a

23   minimum of 2 days and a maximum of 7 days. Each session comprised a 4-min period of seated rest,

24   followed by a 4-min warm-up at a treadmill speed equivalent to 80% GET. Participants then

25   completed 5 x 5-min bouts of treadmill running at a speed equivalent to 20% of the difference between

26   GET and $\dot{V}O_2$ max (Δ20%GET – $\dot{V}O_2$ max; "heavy" exercise; Lansley et al., 2011), interspersed with

27   3-min periods of standing recovery on the treadmill. A passive, standing recovery was selected to

28   remove the potential influence of locomotor–respiratory coupling that could manifest during an active

1 (walking) recovery period (Daley et al., 2013); such coupling might have confounded the assessment

2 of tempo–respiratory entrainment. During the standing recovery periods of a given session,

3 participants were administered one of the following conditions: slow-tempo music; fast-tempo music;

4 or no-music (control). To ensure parity of experience across conditions, headphones were worn during

5 the control condition. The order of conditions was randomized and exercise bouts were completed

6 individually at the same time of day to account for circadian variance.

7 The FS (Hardy & Rejeski, 1989) and FAS (Svebak & Murgatroyd, 1985) were administered

8 immediately prior to the warm-up. Rating of perceived exertion (Borg, 1998) was assessed in the final

9 10 s of each exercise bout. At the end of each bout, the participant straddled the treadmill belt and

10 headphones were placed over his ears. The music tracks had a 1-s fade-in and fade-out to avoid the

11 startle effect (Sandstrom, 2010). Gas exchange and ventilatory function were recorded continuously

12 throughout the aforementioned procedures; HR was recorded at the end of each bout and at the end of

13 each recovery period. The FS and FAS were administered 10 s before the end of the 3-min recovery

14 period. Thereafter, the participant resumed treadmill running. Blood lactate concentration was sampled

15 at resting baseline and immediately following the final music intervention using a 10 µl earlobe

16 capillary sample (Biosen).

17 **2.3. Data Analysis**

18 Following checks to ensure that the data were suitable for parametric analysis, a series of

19 MANOVAs and ANOVAs were applied. A 3 (condition) x 6 (time) MANOVA was used to analyze

20 responses to the Feeling Scale and Felt Arousal Scale; this analysis incorporated the baseline

21 responses. A series of 3 (condition) x 5 (time) ANOVAs were computed for the following dependent

22 variables: RPE, lowest HR during recovery period, mean breathing frequency during recovery (f_R), O_2

23 uptake during recovery ($\dot{V}O_2$), minute ventilation ($\dot{V}_E$) and mean Tidal Volume (V_T) throughout the

24 recovery periods, and respiratory duty cycle (T_{TOT}) during recovery. A series of 3 (condition) x 4

25 (time) ANOVAs was applied to HR (peak) and respiration measures collected during exercise ($\dot{V}O_2$,

26 $\dot{V}_E$, V_T, and T_{TOT}). The four exercise periods following the initial recovery period were included in

27 these analyses to explore the effects of the intervention, which only become relevant from the second

1   exercise bout. A 3 (condition) x 2 (time) ANOVA was applied for pre- and post-exercise blood lactate

2   values. The amount of time respiration rate was entrained with music tempo was analyzed using a 2

3   (condition) x 5 (time) ANOVA.

4   <div align="center">**3. Results**</div>

5   Data screening revealed no univariate ($z < \pm3.29$) or multivariate outliers ($p < 0.001$). Tests of

6   the distributional properties of the data in each cell of the analysis revealed 59 violations ($z > \pm1.96$).

7   Specifically, the data for HR at the end of the recovery period and T_{TOT} during exercise and recovery

8   exhibited positive skewness; therefore, a logarithmic transformation (log10) was applied to normalize

9   these data. Mauchly's test indicated 21 instances in which the sphericity assumption had been

10   violated; therefore appropriate adjustments were applied to the relevant F tests. Descriptive statistics

11   for exercise bouts are presented in Table 3 and for recovery periods in Table 4.

12   **3.1. Affective Responses**

13   RM MANOVA for affective responses (Feeling Scale and Felt Arousal Scale; Table 4)

14   indicated no interaction effects (Pillai's Trace = 0.167, $F[20, 240] = 1.10$, $p = 0.357$, $\eta_p^2 = 0.08$).

15   However, there was a significant effect of condition (Pillai's Trace = 0.425, $F[4, 48] = 3.24$, $p = 0.020$,

16    $\eta_p^2 = 0.21$) and time (Pillai's Trace = 0.438, $F[10, 120] = 3.36$, $p = 0.001$, $\eta_p^2 = 0.22$). Step-down F

17   tests are presented for each measure.

18   **3.1.1. Feeling Scale (FS).** The main effect of condition was significant, $F(1.37, 16.39) = 7.38$,

19    $p = 0.010$, $\eta_p^2 = 0.38$ with follow-up pairwise comparisons indicated that the fast-tempo music

20   condition was rated as significantly more pleasant than the no-music control (95% CI [1.31, 0.44], $p <$

21   0.001; see Figure 1 and Table 4). The main effect of time was nonsignificant, $F(2.01, 24.12) = 0.22$, p

22    $= 0.803$, $\eta_p^2 = 0.02$.

23   **3.1.2. Felt Arousal Scale (FAS).** There was no main effect of condition, $F(2, 24) = 1.16$, $p =$

24   0.330, $\eta_p^2 = 0.09$. The main effect of time was significant, $F(2.20, 26.41) = 5.87$, $p = 0.006$, $\eta_p^2 = 0.33$,

25   with follow-up pairwise comparisons indicating that all recovery bouts resulted in higher levels of

26   arousal compared to baseline.

27

1   **3.2. Psychophysical Response**

2   **3.2.1. Rating of Perceived Exertion (RPE).** There was no condition x time interaction, $F(8,$

3    $96) = 1.72$, $p = 0.103$, $\eta_p^2 = 0.13$, and the main effect of condition was also nonsignificant, $F(2, 24) =$

4   0.67, $p = 0.523$, $\eta_p^2 = 0.05$. There was a main effect of time, $F(1.28, 15.40) = 13.79$, $p = 0.001$, $\eta_p^2 =$

5   0.54, with follow-up pairwise comparisons indicating that levels of exertion were elevated in the final

6   three exercise bouts when compared to the initial two exercise bouts ($p < 0.05$; Table 3).

7   **3.3. Cardiorespiratory Responses**

8   A series of significant main effects of time were revealed in analyses of HR, $\dot{V}_E$, V_T, f_R, and

9   T_{TOT} during exercise bouts and recovery periods with data indicating increased stress as the exercise

10   session progressed ($p < 0.01$).

11   **3.3.1. Heart rate during exercise.** Analysis revealed no condition x time interaction, $F(8, 88)$

12   $= 0.32$, $p = 0.958$, $\eta_p^2 = 0.03$, and no main effect of condition, $F(2, 22) = 0.03$, $p = 0.972$, $\eta_p^2 = 0.01$

13   (Table 3).

14   **3.3.2. Heart rate during recovery.** Analysis indicated a significant condition x time

15   interaction, $F(8, 96) = 2.12$, $p = 0.034$, $\eta_p^2 = 0.16$, which was associated with a large effect. Inspection

16   of the means and standard errors indicated that HR was lower during the control condition in Recovery

17   Period 1 when compared to both music conditions, and that HR was lower during the slow-tempo

18   music condition during Recovery Period 2 when compared to fast-tempo music. Finally, HR was

19   lower during the fast-tempo music condition in Recovery Period 4 when compared to control (see

20   Figure 2 and Table 4). The main effect of condition was nonsignificant, $F(2, 24) = 0.06$, $p = 0.945$, η_p^2

21   $= 0.01$.

22   **3.3.3. Oxygen uptake (% of $\dot{V}O_2$ max).** Oxygen uptake was recorded continuously

23   throughout all exercise and recovery periods and was analyzed as a percentage of maximal aerobic

24   capacity. The condition x time interaction during exercise was nonsignificant, $F(2.67, 32.02) = 0.29$, p

25   $= 0.812$, $\eta_p^2 = 0.02$. There were no main effects of condition, $F(1.26, 15.14) = 1.09$, $p = 0.330$, $\eta_p^2 =$

26   0.08, or time, $F(3, 36) = 0.39$, $p = 0.449$, $\eta_p^2 = 0.03$. Similarly, there was no condition x time

27   interaction for the recovery periods, $F(8, 96) = 0.60$, $p = 0.776$, $\eta_p^2 = 0.05$, and no main effect of

28   condition, $F(1.28, 15.38) = 1.39$, $p = 0.267$, $\eta_p^2 = 0.10$, or time, $F(4, 48) = 1.69$, $p = 0.168$, $\eta_p^2 = 0.12$.

1   **3.3.4. Minute ventilation ($\dot{V}_E$).** There was no condition x time interaction during the exercise

2   bouts, $F(3.04, 36.51) = 0.75$, $p = 0.608$, $\eta_p^2 = 0.06$, or a main effect of condition, $F(2, 24) = 0.00$, $p =$

3   0.997, $\eta_p^2 = 0.00$. During recovery periods, there was no significant condition x time interaction, $F(8,$

4    $96) = 0.90$, $p = 0.523$, $\eta_p^2 = 0.07$, or main effect of condition, $F(2, 24) = 1.18$, $p = 0.324$, $\eta_p^2 = 0.09$.

5   **3.3.5. Tidal volume (V_T).** For measures taken during exercise, there was a nonsignificant

6   condition x time interaction, $F(1.59, 19.10) = 1.70$, $p = 0.211$, $\eta_p^2 = 0.12$, and a nonsignificant main

7   effect of condition, $F(2, 24) = 0.56$, $p = 0.583$, $\eta_p^2 = 0.04$. There was no condition x time interaction,

8    $F(8, 96) = 0.83$, $p = 0.583$, $\eta_p^2 = 0.06$, or main effect of condition, $F(2, 24) = 2.08$, $p = 0.147$, $\eta_p^2 =$

9   0.15, for recovery period data.

10   **3.3.6. Respiratory frequency (f_R).** Data collected during exercise indicated no condition x

11   time interaction, $F(1.86, 22.37) = 1.25$, $p = 0.302$, $\eta_p^2 = 0.10$, and similarly, a nonsignificant main

12   effect of condition, $F(2, 24) = 0.28$, $p = 0.756$, $\eta_p^2 = 0.02$. During recovery periods, there was no

13   significant condition x time interaction, $F(3.53, 42.30) = 0.28$, $p = 0.870$, $\eta_p^2 = 0.02$, or main effect of

14   condition, $F(2, 24) = 0.42$, $p = 0.663$, $\eta_p^2 = 0.03$.

15   **3.3.7. Respiratory duty cycle (T_{TOT}).** There was no significant condition x time interaction

16   during exercise bouts, $F(1.51, 18.14) = 0.81$, $p = 0.569$, $\eta_p^2 = 0.06$. There was also no main effect of

17   condition, $F(1.36, 16.65) = 1.36$, $p = 0.273$, $\eta_p^2 = 0.10$. During the recovery periods, there was no

18   significant condition x time interaction, $F(8, 96) = 0.18$, $p = 0.994$, $\eta_p^2 = 0.01$, or main effect of

19   condition, $F(2, 24) = 1.77$, $p = 0.193$, $\eta_p^2 = 0.13$.

20   **3.4. Blood Lactate**

21   There was no significant condition x time interaction, $F(2, 24) = 1.12$, $p = 0.342$, $\eta_p^2 = 0.09$,

22   and no main effect of condition, $F(2, 24) = 0.70$, $p = 0.509$, $\eta_p^2 = 0.05$. There was a significant main

23   effect of time, $F(1, 12) = 28.22$, $p < 0.001$, $\eta_p^2 = 0.70$, indicating that post-exercise values were higher

24   ($M = 4.40 \pm 0.61$) than baseline ($M = 1.05 \pm 0.09$).

25   **3.5. Tempo-Respiratory Entrainment**

26   The condition x time interaction effect was nonsignificant ($F[4, 48] = 0.58$, $p = 0.676$, $\eta_p^2 =$

27   0.05), as were the main effects of condition and time ($p > 0.05$).

28

1   **4. Discussion**

2   The purpose of this study was to assess the influence of music on acute psychological and

3   cardiorespiratory recovery in between bouts of high-intensity exercise among trained participants. Our

4   research hypothesis was not supported given that fast-tempo music, rather than slow-tempo music,

5   positively influenced affective responses in all recovery periods when compared to a no-music control

6   condition. Furthermore, music does not appear to facilitate acute cardiorespiratory recovery in

7   between bouts of high-intensity treadmill exercise.

8   **4.1. Affective Responses**

9   Listening to fast-tempo, positively-valenced music (125–135 bpm) during the 3-min recovery

10   periods engendered a more pleasant experience when compared to a no-music control eliciting a FS

11   score of ~1 higher ($p = 0.010$; $\eta_p^2 = 0.38$). This was a consistent finding across each of the five

12   recovery periods (see Figure 1), and was associated with a large effect size indicating a robust result.

13   The positive affective response to music is concordant with other exercise-related studies (e.g., Stork

14   et al., 2015) and the efficacy of fast-tempo music in this instance could be associated with the HR

15   range recorded in the present study. A corpus of work has explored the relationship between exercise

16   HR and preference for music tempo (see Karageorghis & Jones, 2014). This work shows that,

17   regardless of exercise intensity (40–90% maxHRR), there is a preference for fast-tempo music during

18   treadmill exercise and cycle ergometry. These studies explored the application of in-task music

19   (during exercise) with working heart rates ranging from ~110 to ~180 b·min^{-1} and participants in the

20   present study exhibited heart rates ranging from ~105 to ~180 b·min^{-1} during recovery periods. It

21   appears that fast-tempo music elicits the most positive affective responses when heart rates are

22   elevated, whether this is during exercise or recovery periods.

23   The arousal reported by participants during the recovery periods increased significantly from

24   baseline ($p = 0.006$; FAS = 3.08 ± 0.17), but remained stable throughout recovery periods (FAS = 3.77

25   ± 0.17 [Recovery Period 1]; 3.82 ± 0.23 [Recovery Period 2]; 3.87 ± 0.27 [Recovery Period 3]; 3.87 ±

26   0.29 [Recovery Period 4]; 3.56 ± 0.23 [Recovery Period 5]). Although the fast-tempo music selections

27   were rated as more highly-arousing than the slow-tempo tracks during the music selection process

28   (Stage 1), this was not reflected during the recovery periods. It appears that arousal increased

1   independently of the music administered and that the exercise was sufficient to significantly increase

2   arousal from baseline. The elevated arousal resulting from the intervals may have been sufficient for

3   participants to maintain an optimal arousal level for the session without any need for music to help in

4   regulating arousal.

5   **4.2. Cardiorespiratory Responses**

6   The significant interaction effect of condition x time for the HR recovery ($p = 0.034$, $\eta_p^2 =$

7   0.16) indicated that participants exhibited a lower HR at the end of the first recovery period during

8   control, and a lower HR during the second recovery period in the slow-tempo condition when

9   compared to the fast-tempo condition. Given that participants were engaged in prolonged exercise

10   above the GET, there was substantial cardiorespiratory drift, during which oxygen uptake and

11   ventilation increased progressively, as illustrated by the multiple main effects of time. Therefore, any

12   music-moderated effect on recovery HR would likely manifest in the early recovery periods. Despite

13   the HR interactions observed during recovery, there was no subsequent influence on exercise HR or

14   associated cardiorespiratory variables (see Table 3). This suggests that, in this population, lower HR

15   during early recovery periods is of limited physiological benefit in subsequent bouts of exercise.

16   **4.3. Tempo-Respiratory Entrainment**

17   Previous studies reported entrainment of breathing and music rhythms at rest (e.g., Haas et al.,

18   1986; Bernadi et al., 2005), but the present study did not replicate these findings in an exercise

19   context. Despite Khalfa et al.'s (2008) suggestion that entrainment is a partially conscious process,

20   exercise ventilation is controlled by neural and humeral factors to enable the delivery of oxygen and

21   elimination of carbon dioxide (Forster et al., 2012). Consequently, it appears that when ventilation is

22   high, maintenance of homeostatic equilibrium will be the predominating factor in the control of

23   ventilation. During the first recovery period when ventilation was lowest, values were in excess of

24   three times those at rest (36.8 ± 10.7 vs. 11.2 ± 2.9 L·min^{-1}) and it seems as though such a high demand

25   restricts the likelihood of entrainment being manifest. The present results suggest that only resting

26   respiration would be susceptible to the subtle influence of music tempo on respiratory function.

27   The conscious and unconscious aspects of different types of entrainment may be a salient

28   factor (Phillips-Silver et al., 2010). Entrainment between musical tempo and HR is an unconscious

1   process. Nonetheless, entrainment between respiration rate and music tempo can be either conscious

2   or unconscious given that humans breathe without conscious cognitive control, but can also choose to

3   regulate their breathing rate. From an information processing perspective, the notion of a limited

4   attentional capacity may be relevant when considering the capacity to process, and entrain with,

5   external stimuli such as music during periods of physical stress. Rejeski's (1985) model of parallel

6   processing indicates that informational and emotional components are processed in parallel, rather

7   than in sequence. Furthermore, as exercise intensity increases, informational cues become stronger and

8   occupy the limited capacity of channels between preconscious and focal awareness. It might be that

9   during recovery from high-intensity exercise, internal informational cues predominate and there is

10 insufficient capacity remaining to process musical stimuli in order to consciously manipulate

11 respiration rate.

12 **4.4 Technical Considerations**

13   A high number of participants ($n = 7$) were unable to complete all of the testing sessions. We

14 applied an exercise intensity of $\Delta20\text{-}\dot{V}O_2$ max, which is considered to be "heavy" exercise (Lansley et

15 al., 2011). This typifies an intensity at which athletes train for periods of ~3 min. The 5-min bout was

16 selected to allow for a relative steady-state in physiological responses, and the 3-min recovery period

17 to enable sufficient exposure to the musical stimuli (i.e., the musical stimuli would have long enough

18 to take effect). However, two participants were unable to tolerate the physical stress associated with

19 the extended interval duration. Future studies might seek to explore the role of music in promoting

20 recovery during alternative protocols such as the so-called *practical model* of low volume, high

21 intensity interval training (Little, Safdar, Wilkin, Tarnopolsky, & Gibala, 2010). The remaining five

22 participants withdrew owing to injury ($n = 3$) or competitive commitments ($n = 2$).

23 **4.5. Practical Implications**

24   The hypothesis that slow-tempo, positively-valenced music would promote the most positive

25 psychological state during recovery was based on previous suggestions (Terry & Karageorghis, 2011),

26 and findings that sedative music promotes effective psychological and physiological exercise recovery

27 (Jing & Xudong, 2008). There are some notable differences between previous work and the present

28 study that may explain the nature of our results. First, previous work has framed post-task, or

1   recuperative, music in the context of the final phase of an exercise session (i.e., no further bouts of

2   exercise within the session) but the present study sought to explore the utility of music as an aid to

3   recovery that took place *in between* repeated bouts of exercise. This is likely a seminal difference and

4   would suggest the need for terminological distinction. Accordingly, it is proposed that the term *respite*

5   *music* is adopted by researchers and practitioners to more accurately describe the application of music

6   during periods of recovery within an exercise session. The proposed term provides a useful

7   counterpoint to *recuperative music*, which refers to sedative music that is applied immediately after an

8   exercise or training session (Terry & Karageorghis, 2011).

9   The capacity for music to positively enhance the exercise experience has been demonstrated in

10   a number of studies (e.g., Hutchinson et al., 2011; Karageorghis & Jones, 2014). The present study

11   extends that work to suggest that fast-tempo, positively-valenced music can be used to afford an

12   effective respite that positively enhances the pleasure experienced during a high-intensity interval

13   session. The concept of "affective rebound" (Ekkekakis et al., 2008) demonstrates that affective

14   valence returns to pre-exercise levels almost immediately following cessation of exercise. Present data

15   indicate that pleasure can be enhanced beyond pre-exercise levels through the administration of fast-

16   tempo, positively-valenced music during the rest periods of an interval running session in trained

17   participants. Furthermore, there are numerous studies reporting a link between acute affective

18   responses to exercise and subsequent adherence to exercise (see Rhodes & Kates, 2015 for a review);

19   interventions that can enhance acute affective responses in untrained populations warrant additional

20   investigation.

21   Given the typical affective responses during exercise, as depicted in the dual-mode model

22   (Ekkekakis, 2003), the high-intensity exercise bout itself will not typically result in positive affective

23   responses but the rest periods in between exercise bouts offer an opportunity to ameliorate this

24   displeasure. Therefore, the use of fast-tempo, positively-valenced music appears to promote a more

25   pleasurable and thus *tolerable* exercise experience.

26   **5. Conclusion**

27   The present findings indicate that fast-tempo, positively-valenced music engenders positive

28   affective responses in the acute recovery phases of high-intensity interval training performed by

1   middle-distance runners. This finding is of relevance to coaches and practitioners working with

2   athletes and recreational exercisers, as it offers an easily implementable intervention by which to

3   increase the pleasure experienced during a physically demanding session. The findings are in accord

4   with other work indicating that music can enhance affective responses in a high-intensity exercise

5   context (e.g., Stork & Martin Ginis, 2016). The recorded physiological responses do not provide

6   robust evidence that slow or fast-tempo music expedites recovery in this context. Future research

7   might seek to examine the effects of music during the recovery periods following exercise performed

8   at lower intensities; specifically focusing on the extent to which music promotes respiratory

9   entrainment. A terminological distinction has been proposed herein to differentiate *recuperative* music

10   (applied post-task) from *respite* music (applied in between bouts of exercise). Respite music has

11   pleasant–arousing qualities, in line with the activated state of the organism during a brief recovery

12   period, whereas recuperative music that is employed on cessation of exercise is characterized by

13   pleasant–relaxing qualities.

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19

1   Table 1

2   *Music Tracks Administered in the Experimental Conditions*

Track Title	Artist(s)	Year of release	Official bpm	Affect Rating (*M*)	Arousal Rating (*M*)
Slow tempo					
At The River	Groove Armada	1998	68	6.83 ± 1.47	2.83 ± 0.41
Can You Feel The Love Tonight	Elton John	1994	67	6.33 ± 1.21	3.00 ± 1.10
I Wanna Be Yours	Arctic Monkeys	2013	67	6.17 ± 1.94	3.50 ± 0.55
At Last	Etta James	1960	56	6.07 ± 2.07	2.50 ± 0.55
All You Ever Wanted	The Black Keys	2008	59	6.50 ± 1.64	3.33 ± 0.82
Fast tempo					
Old Yellow Bricks	Arctic Monkeys	2007	135	7.00 ± 1.10	6.67 ± 0.82
Satisfaction	Rolling Stones	1965	136	6.67 ± 0.82	7.67 ± 1.03
Hideaway	Kiesza	2014	123	6.33 ± 1.03	6.67 ± 0.82
What Is Love	Haddaway	1993	124	6.67 ± 1.75	7.67 ± 0.52
Fever	The Black Keys	2014	128	6.17 ± 1.47	6.83 ± 0.98

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1   Table 2

2   *Peak Physiological Responses to Incremental Treadmill Running, mean ± SD (N = 13)*

Variables	Rest	Max
Treadmill Speed (km·hr^{-1})	0 ± 0	20 ± 2
$\dot{V}O_2$ (L·min^{-1})	0.38 ± 0.09	4.34 ± 0.50
$\dot{V}O_2$ (ml·kg·min^{-1})	5.4 ± 1.1	61.6 ± 6.1
$\dot{V}CO_2$ (L·min^{-1})	0.36 ± 0.09	5.12 ± 0.53
RER	0.95 ± 0.13	1.18 ± 0.07
HR (b·min^{-1})	57 ± 9	196 ± 7
$\dot{V}_E$ (L·min^{-1})	11.7 ± 2.9	155 ± 20.8
V_T (L)	0.84 ± 0.24	2.74 ± 0.38
f_R (br·min^{-1})	14.6 ± 2.9	58.7 ± 10.1
T_{TOT} (s)	4.4 ± 1.1	1.0 ± 0.2
RPE$_{CR10}$	0 ± 0	10 ± 1

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12   *Note.* $\dot{V}O_2$, O_2 uptake; $\dot{V}CO_2$, CO_2 output; RER, respiratory exchange ratio; HR, heart rate; $\dot{V}_E$,
13   minute ventilation; V_T, tidal volume; f_R, respiratory frequency; T_{TOT}, respiratory duty cycle; RPE$_{CR10}$,
14   rating of perceived exertion.

Table 3

Descriptive Statistics for all Dependent Variables Recorded during Exercise Bouts (M ± SD)

|	EFFORT 1			EFFORT 2			EFFORT 3			EFFORT 4			EFFORT 5		
	Slow	Fast	Control	Slow	Fast	Control	Slow	Fast	Control	Slow	Fast	Control	Slow	Fast	Control
$\dot{V}O_2$ (L·min^{-1}) [a]	3.37 ± 5.56	3.39 ± 5.26	3.22 ± 6.91	3.27 ± 5.64	3.32 ± 5.26	3.13 ± 6.38	3.27 ± 5.92	3.32 ± 5.59	3.12 ± 7.00	3.30 ± 5.78	3.33 ± 5.56	3.16 ± 5.80	3.31 ± 6.03	3.30 ± 5.80	3.14 ± 5.31
$\dot{V}O_2$ (%max) [b]	78 ± 10	79 ± 12	74 ± 12	76 ± 11	77 ± 13	72 ± 12	76 ± 12	77 ± 13	72 ± 13	76 ± 11	77 ± 13	73 ± 11	76 ± 12	77 ± 14	73 ± 10
$\dot{V}CO_2$ (L·min^{-1})	3.37 ± 5.64	3.41 ± 5.80	3.34 ± 7.22	3.16 ± 5.68	3.20 ± 5.64	3.12 ± 6.15	3.12 ± 6.00	3.19 ± 5.93	3.09 ± 6.65	3.16 ± 5.84	3.19 ± 5.92	3.12 ± 5.81	3.15 ± 6.13	3.15 ± 6.21	3.09 ± 5.69
HR (b·min^{-1}) [c]	171.50 ± 6.97	171.38 ± 5.85	171.85 ± 9.27	175.46 ± 7.99	175.15 ± 6.91	175.46 ± 9.66	179.54 ± 7.73	178.69 ± 6.50	179.08 ± 10.02	181.00 ± 8.24	181.08 ± 6.59	181.46 ± 9.88	183.00 ± 8.05	182.08 ± 7.2	182.92 ± 9.17
$\dot{V}_E$ (L·min^{-1}) [c]	94.13 ± 25.38	93.38 ± 24.67	93.87 ± 22.93	91.84 ± 24.59	93.93 ± 21.41	93.96 ± 21.45	96.65 ± 25.13	95.99 ± 24.28	96.48 ± 22.21	98.77 ± 25.85	98.14 ± 24.73	98.04 ± 21.39	99.79 ± 26.18	99.51 ± 25.2	99.04 ± 23.00
V_T (L·min^{-1}) [c]	2.41 ± 0.32	2.48 ± 0.29	2.43 ± 0.26	2.25 ± 0.35	2.17 ± 0.26	2.25 ± 0.29	2.17 ± 0.30	2.21 ± 0.29	2.23 ± 0.29	2.14 ± 0.30	2.19 ± 0.30	2.08 ± 0.24	2.13 ± 0.28	2.16 ± 0.29	2.03 ± 0.27
f_R (br·min^{-1}) [c]	39.17 ± 9.36	37.83 ± 8.96	38.71 ± 8.31	41.11 ± 10.24	43.10 ± 6.56	42.09 ± 8.90	44.73 ± 10.00	43.56 ± 9.52	43.71 ± 9.32	46.65 ± 11.50	44.97 ± 9.66	47.10 ± 7.93	47.16 ± 11.89	46.48 ± 10.5	48.60 ± 8.40
T_{TOT} (s) [c]	1.67 ± 0.50	1.64 ± 0.48	1.69 ± 0.45	1.60 ± 0.50	1.39 ± 0.25	1.56 ± 0.46	1.48 ± 0.47	1.42 ± 0.51	1.49 ± 0.45	1.43 ± 0.50	1.38 ± 0.52	1.35 ± 0.27	1.42 ± 0.49	1.35 ± 0.54	1.30 ± 0.25
RPE_{CR10} [c]	4.77 ± 1.09	4.69 ± 1.25	4.69 ± 1.18	4.77 ± 1.17	5.15 ± 1.41	5.08 ± 1.32	5.38 ± 1.39	5.62 ± 1.45	5.31 ± 1.38	5.77 ± 1.36	5.77 ± 1.48	5.85 ± 1.41	5.85 ± 1.34	6.08 ± 1.80	6.23 ± 1.54

Note. $\dot{V}O_2$, O_2 uptake; $\dot{V}CO_2$, CO_2 output; HR, heart rate; $\dot{V}_E$, minute ventilation; V_T, tidal volume; f_R, respiratory frequency; T_{TOT}, respiratory duty cycle; RPE_{CR10}, rating of perceived exertion. [a] = significant condition x time interaction, [b] = significant main effect of condition, [c] = significant main effect of time.

Table 4

Descriptive Statistics for all Dependent Variables Recorded during Recovery Periods (M ± SD)

	RECOVERY 1			RECOVERY 2			RECOVERY 3			RECOVERY 4			RECOVERY 5		
	Slow	Fast	Control	Slow	Fast	Control	Slow	Fast	Control	Slow	Fast	Control	Slow	Fast	Control
$\dot{V}O_2$ (L.min-1)	1.06 ± 0.25	1.10 ± 0.24	0.99 ± 0.32	1.09 ± 0.27	1.11 ± 0.27	1.00 ± 0.34	1.06 ± 0.36	1.11 ± 0.27	1.03 ± 0.34	1.09 ± 0.30	1.16 ± 0.33	1.03 ± 0.31	1.11 ± 0.30	1.11 ± 0.29	1.02 ± 0.31
$\dot{V}CO_2$ (L·min^{-1})	1.18 ± 0.30	1.23 ± 0.30	1.16 ± 0.40	1.18 ± 0.33	1.19 ± 0.32	1.13 ± 0.41	1.13 ± 0.43	1.19 ± 0.31	1.15 ± 0.43	1.16 ± 0.35	1.23 ± 0.36	1.15 ± 0.46	1.17 ± 0.35	1.19 ± 0.34	1.14 ± 0.42
HR (b·min^{-1}) [a, c]	107.00 ± 8.74	106.69 ± 6.38	104.31 ± 10.42	110.92 ± 7.57	114.15 ± 8.13	112.85 ± 12.19	119.08 ± 8.54	120.54 ± 8.18	120.92 ± 12.47	125.77 ± 12.90	124.31 ± 9.52	126.92 ± 13.02	129.31 ± 11.21	128.38 ± 9.67	127.77 ± 12.75
$\dot{V}_E$ (L·min^{-1}) [c]	36.15 ± 10.57	37.92 ± 11.34	36.30 ± 11.08	36.74 ± 11.49	38.54 ± 11.66	37.98 ± 11.08	36.60 ± 12.64	40.05 ± 12.31	39.74 ± 12.95	38.92 ± 12.10	41.44 ± 12.70	40.48 ± 14.63	39.68 ± 11.87	41.27 ± 12.60	41.84 ± 15.01
V_T (L·min^{-1}) [c]	1.36 ± 0.29	1.40 ± 0.22	1.40 ± 0.23	1.31 ± 0.27	1.34 ± 0.24	1.35 ± 0.28	1.25 ± 0.25	1.31 ± 0.22	1.37 ± 0.27	1.29 ± 0.25	1.34 ± 0.27	1.31 ± 0.25	1.25 ± 0.23	1.26 ± 0.25	1.33 ± 0.24
f_R (br·min^{-1}) [c]	26.55 ± 5.39	27.11 ± 5.86	26.19 ± 6.91	28.37 ± 29.37	29.37 ± 8.66	29.10 ± 6.91	29.26 ± 7.62	30.81 ± 7.99	29.74 ± 9.75	30.73 ± 8.91	31.65 ± 9.01	31.47 ± 11.37	32.26 ± 9.58	33.15 ± 9.04	32.28 ± 11.99
T_{TOT} (s) [c]	2.54 ± 0.60	2.34 ± 0.58	2.59 ± 0.78	2.44 ± 0.74	2.32 ± 0.95	2.48 ± 0.91	2.39 ± 0.74	2.23 ± 0.91	2.39 ± 0.84	2.30 ± 0.76	2.17 ± 0.87	2.29 ± 0.75	2.22 ± 0.81	2.03 ± 0.72	2.30 ± 0.91
ENT (%)	20.77 ± 15.53	19.23 ± 10.38	-	20.00 ± 12.25	20.00 ± 12.25	-	17.69 ± 12.35	20.77 ± 10.38	-	26.15 ± 13.87	26.15 ± 17.10	-	24.62 ± 13.30	16.92 ± 13.77	-
FS [b]	2.08 ± 1.19	2.54 ± 1.05	1.46 ± 1.51	2.08 ± 1.19	2.54 ± 0.88	1.54 ± 0.97	2.08 ± 1.50	2.46 ± 0.97	1.54 ± 1.20	2.0 ± 1.35	2.54 ± 1.71	1.62 ± 1.12	2.08 ± 1.55	2.69 ± 1.49	1.69 ± 1.75
FAS [c]	3.46 ± 0.97	4.15 ± 0.69	3.69 ± 0.75	3.69 ± 1.18	4.00 ± 0.71	3.77 ± 1.09	3.92 ± 1.26	3.85 ± 1.07	3.85 ± 0.99	3.54 ± 1.27	4.15 ± 1.14	3.92 ± 1.12	3.54 ± 1.33	3.92 ± 0.86	3.23 ± 1.36

Note. $\dot{V}O_2$, O_2 uptake; $\dot{V}CO_2$, CO_2 output; HR, heart rate; $\dot{V}_E$, minute ventilation; V_T, tidal volume; f_R, respiratory frequency; T_{TOT}, respiratory duty cycle; ENT, proportion of respite time spent entrained; FS, Feeling Scale; FAS, Felt Arousal Scale. [a] = significant condition x time interaction, [b] = significant main effect of condition, [c] = significant main effect of time.
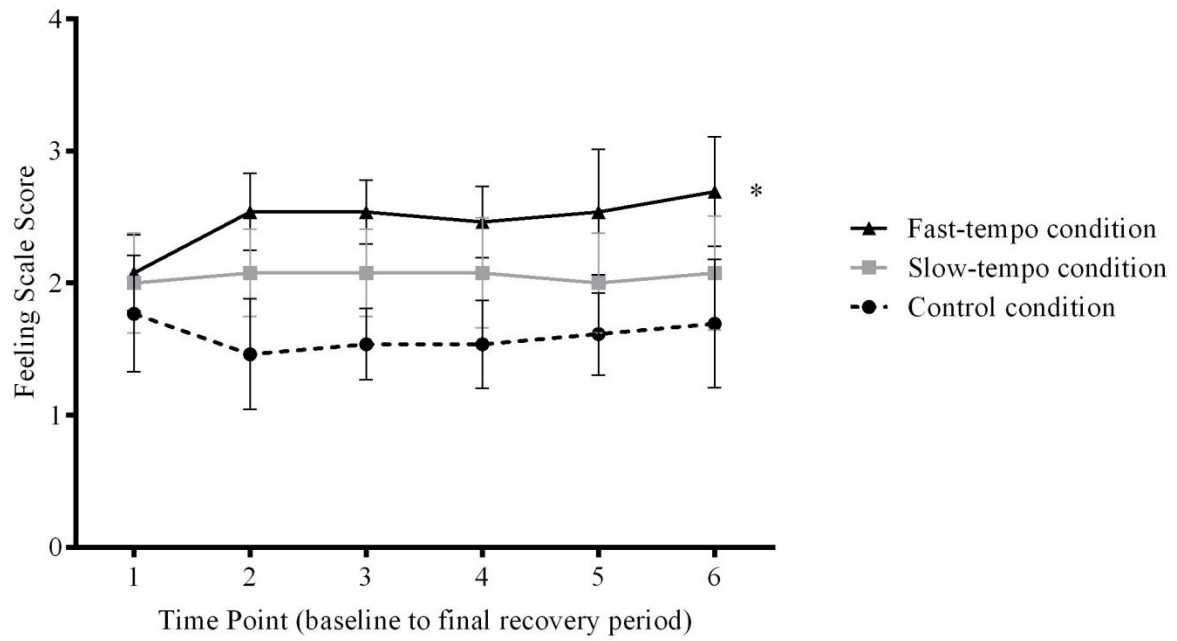
Fig. 1. Significant main effect of condition for Feeling Scale scores. *$p = 0.010$; fast-tempo music > control condition.
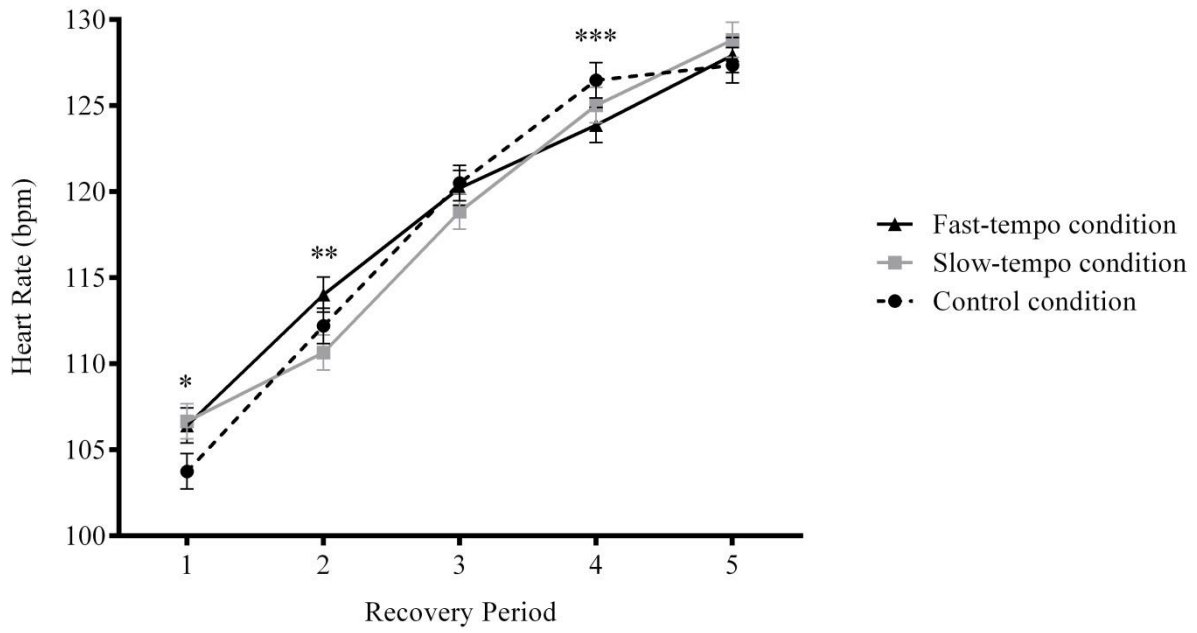
Fig. 2. Significant condition x time interaction effect for heart rate during recovery ($p = 0.034$). * control condition < slow- and fast-tempo condition, ** slow-tempo < fast-tempo, *** fast-tempo < control condition.