When it HIITs You, You Feel No Pain: Psychological and Psychophysiological Effects of Respite–Active Music in High-Intensity Interval Training

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Abstract

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Recovery can be defined as the organism's return to baseline or resting state (Kellman & Beckmann, 2017). The enhancement of recovery has implications for the degree to which recreationally active individuals both enjoy and adhere to exercise (Martin & Woods, 2012). Most of the literature addressing the psychological and psychophysiological effects of music in the exercise domain has focused upon pretask and in-task applications (see e.g., Terry, Karageorghis, Curran, Martin, & Parsons-Smith, 2020 for a meta-analysis); scant attention has been given to investigation of the use of music for recovery. One important distinction, not always made explicit by researchers, has entailed the use of music for movement-based recovery, known as "active recovery", and static-based recovery, known as "passive recovery" (Karageorghis, 2017).

Jones, Tiller, and Karageorghis (2017) coined the term "respite music" for music applied during periods of recovery *within* an exercise session but there is a need for greater conceptual clarity given the different ways in which respite music can be applied. In the Jones et al. study, music was applied in the recovery periods in between high-intensity bouts when participants were taking passive (i.e., static) recovery. We propose that the term, "respite–passive music" represents greater precision for such instances, whereas "respite–active music" more accurately reflects the present application (i.e., participants cycled at a low intensity during a recovery period while listening to music).

High-intensity interval training (HIIT) is a short-duration form of exercise that entails a series of short, high-intensity efforts, punctuated by recovery periods (Stork, Banfield, Gibala, & Martin Ginis, 2017). Studies have shown that several weeks of HIIT can bring benefits to physical health that are analogous to those derived from the long-duration, aerobic-type exercise that is more commonly adopted by the general public (Batacan, Duncan, Dalbo, Tucker, & Fenning, 2017). Such health benefits can also be realized by at-risk and diseased populations (Gibala et al., 2014; Quindry, Franklin, Chapman, Humphrey, & Mathis, 2019). Albeit there is a growing body of evidence showing the physiological benefits of HIIT, from a public health/adherence perspective, there is a significant shortcoming. It is widely acknowledged that people can find HIIT to be rather unpleasant; a factor that can undermine long-term participation in such activity (see e.g., Decker & Ekkekakis, 2017; Ekkekakis, 2020).

Given the aforementioned health benefits of interval-type exercise, coupled with the likelihood of it being perceived as unpleasant, there has been growing interest in the application of music as a means by which to ameliorate negative psychological responses, such as affective decline, low enjoyment, and high levels of perceived exertion (e.g., Jones et al., 2017; Stork, Kwan, Gibala, & Martin Ginis, 2015). Hypothetically, using music to enhance the experience of interval-type exercise may have positive consequences for future participation (i.e., exercise adherence; see Stork, Karageorghis, & Martin Ginis, 2019).

The last decade has seen the emergence of an extensive corpus of work addressing the effects of music during high-intensity exercise (e.g., Jones et al., 2017; Karageorghis et al., 2009; Karageorghis et al., 2018; Stork et al., 2015). In HIIT protocols, the use of environmental stimuli to enhance recovery or respite periods has yet to be investigated in a systematic manner and provides tantalizing opportunities for researchers in the realm of sport and exercise psychology.

Recent work has shown the degree to which affective memory and affective forecasting can influence physical activity behaviors (e.g., Ekkekakis, Zenko, Ladwig, & Hartman, 2018). Moreover, the collection of physiological measures (e.g., heart rate) alongside psychological measures (e.g., self-reported affective responses) is likely to proffer a better understanding of the effects that environmental stimuli can have during HIIT. Among the body of work that has explored how bodily pulses can resonate with music pulses, Jones et al. (2017) found that there were minimal effects associated with the application of slowand fast-tempo music on breathing and heart rates.

In their examination of recuperative music, Karageorghis et al. (2018) indicated that fast-tempo music inhibited HR recovery following exhaustive exercise. If a targeted music intervention can expedite physiological recovery during an interval-type session, intuitively, this is likely to engender a more pleasant exercise experience. Nonetheless, a salient consideration in any such session is that, an intervention that engenders a positive effect on recovery, does not compromise performance in the next exercise bout. Therefore, a balance needs to be struck between the amelioration of negative affect during a recovery period, and maintenance of the degree of psychomotor arousal needed to optimize power output in the ensuing exercise bout. That is why, in the present study, medium-tempo music was used for the recovery periods and not slow-tempo music, as in past work of a similar nature (e.g., Hutchinson & O'Neil, 2020; Jones et al., 2017).

Music tempo is central to the biomusicological phenomenon of *entrainment*, which concerns bodily pulses such as heart/respiration rate and brainwaves being drawn into a common oscillation with musical tempo (Terry et al., 2020). This phenomenon has yet to be examined in the context of high-intensity exercise with the application of respite–active music. Accordingly, the purpose of the present study was to investigate the effects of respite–active music on the psychological experiences and physiological responses of recreationally active individuals who were administered a HIIT protocol in a laboratory setting.

Based on findings from previous research (Eliakim, Bodner, Meckel, Nemet, & Eliakim, 2012; Hutchinson & O'Neil, 2019; Karageorghis & Jones, 2014), we hypothesized that recovery periods accompanied by medium-tempo, respite–active music (120–125 bpm) would be superior in terms of psychological (i.e., higher affective valence/enjoyment/pleasure scores and less association) and psychophysical (i.e., lower RPE) outcome measures when compared to fast-tempo, respite–active music (135–140 bpm), and a no-music control condition (H_1). In accord with related literature pertaining to the application of recuperative music following exhaustive exercise (Karageorghis et al., 2018), we expected lower average heart rate and the lowest absolute heart rate in recovery periods accompanied by medium-tempo music when compared to fast-tempo music and control conditions (H_2). We did not expect any differences among conditions in terms of average and peak heart rate during the high-intensity exercise bouts and so the null hypothesis was tested (H_3). We did not expect the experimental manipulations–applied only to recovery periods–to have any significant effect on measures taken at the end of the exercise bouts (H_4).

Method

Study design and Power Analysis

A fully counterbalanced, within-subjects design was employed with one control condition (no music) and two experimental conditions (medium-tempo and fast-tempo music). Using a more conservative effect size than that derived from Jones et al. (2017; η_p^2 = 0.08) owing to a more subtle tempo manipulation between experimental conditions, an *a priori* power analysis using a small-to-medium effect size (η_p^2 = 0.05), an alpha level of .05, power at .8, indicated that a sample of 21 participants would be required to detect differences in a twoway repeated-measures (RM) 3 (Condition) × 8 (Time [HIIT exercise bouts and active recovery periods]) ANOVA of Feeling Scale scores (the primary outcome measure). An additional three participants were recruited to guard against deletions due to outliers and to enable full counterbalancing of conditions.

Participants

With institutional ethics approval, 24 participants (12 women and 12 men; M_{age} 22.5 years, SD = 1.7 years; M_{height} = 175.3 cm, SD = 9.5 cm; M_{mass} 80.7 kg, SD = 12.6 kg; $M_{weekly\ vigorous\ activity}$ 60 min, SD = 25.8 min; $M_{weekly\ moderate\ activity}$ = 130 min; SD = 70.5 min) were recruited through word of mouth at a university in _____________ and all provided written informed consent. Participant inclusion criteria were that they: a) were aged 18–25 years; b) could fully comprehend spoken and written English; c) were healthy; and d) participated in at least 150 min/week of moderate physical activity (PA) and/or more than 75 min/week of vigorous PA over the previous 3 months (World Health Organization, 2010). Participants were of a similar age in order to limit the effects of age on music preference, thereby addressing a potential confound (Karageorghis & Terry, 1997). Similarly, participants were recruited in such a way that there was a degree of homogeneity in their weekly levels of physical activity. This is important given that physical activity status is known to influence affective responses to exercise (Magnan, Kwan, & Bryan, 2013).

Procedures

Potential volunteers were screened to ensure they met the study inclusion criteria and determine any significant health problems that might prevent them from engaging in a HIIT protocol. The Physical Activity Readiness Questionnaire (PAR-Q) and the International Physical Activity Questionnaires (IPAQ) were administered prior to each participant's first laboratory visit. Participants did not report any significant health concerns and weekly active minutes confirmed that participants met the aforementioned inclusion criteria.

Baseline fitness testing and familiarization. We recorded the participant's height and mass then explained the procedures associated with completion of a maximal exercise test on an electronically-braked cycle ergometer (Lode Excalibur Sport; Lode B.V., Groningen, the Netherlands). The test comprised a 4-min warm-up at 50 W followed by a ramped protocol with 20 W increases each minute until volitional exhaustion. Peak wattage was recorded and used in subsequent experimental trials. The protocol adhered to criteria for maximal tests (see Porszasz, Casaburi, Somfay, Woodhouse, & Whipp, 2003); specifically that the protocol: a) included a low initial metabolic demand; b) provided a constant linear increase in work rate; and c) brought participants to the limit of tolerance in ~10 min. Following a 10-min recovery period, the participant completed a HIIT habituation session with 4 × 60 s bouts interspersed with 90 s recovery (no music). The workload for the exercise bouts of the HIIT session was 100% Wmax.

The participant was asked to report her/his rating of perceived exertion by use of the CR-10 RPE scale (Borg, 1998), state attention by use of the Attention Scale (Tammen, 1996), pleasure by use of the Feeling Scale (Hardy & Rejeski, 1989), and perceived activation by use of the Felt Arousal Scale (Svebak & Murgatroyd, 1985) in the final 15 s of each 60-s high-intensity exercise bout and before commencement of any music. The same measures were administered in the final 15 s of each 90-s recovery period but in the reverse order to minimize common method variance. Remembered pleasure was assessed using a 200-point scale (Zenko, Ekkekakis, & Ariely, 2016), which ranges from -100 (*very unpleasant*) to 100 (*very pleasant*) and 0 represents a neutral response. Enjoyment was measured using the Physical Activity Enjoyment Scale (PACES; Kendzierski & DeCarlo, 1991); scores can range from 18 to 126, with 72 representing the midpoint and thus a neutral score. These scales were administered immediately following the exercise bout, once the participant had dismounted the cycle ergometer. At the end of the session, the participant was led through a warm-down and encouraged to ask any questions s/he might have.

Experimental trials. After a minimum of 48 hours following her/his pretest familiarization visit to the laboratory, the participant completed a HIIT session under three conditions: a) medium-tempo music (120–125 bpm); b) fast-tempo music (135–140 bpm); and c) a no-music control. The three HIIT test conditions were administered ~48–72 hours apart. Each participant was instructed to maintain her/his typical habits in terms of both sleep and diet. Moreover, the participant was asked to desist from any other form of physical activity for the entire day when s/he was due to make a visit to the laboratory. Prior to initiating any of the physical tasks, each participant had the procedures explained to her/him in full, and was afforded an opportunity to ask questions. Each participant's heart rate was recorded throughout by use of a chest-strap transmitter linked to a wristwatch (Polar H10; Polar Electro Oy, Kempele, Finland), with exercise bout peak and average HR values as well as recovery low and average values recorded for each HIIT stage. Eight HIIT stages were included, each with an exercise bout and an ensuing recovery period. The stages were treated as distinct units for analytical purposes.

The HIIT session comprised a 4-min warm-up at 50 W followed immediately by the first 60-s exercise bout (100% Wmax) at 75–80 rpm. The exercise bout was followed by a 90-s recovery period at 50 W wherein the participant continued to cycle at 65–70 rpm. A further seven exercise bouts were completed, each separated by a 90-s recovery period. Following the final exercise bout, the participant completed a 90-s recovery period at 50 W and then dismounted the cycle ergometer.

It should be noted that the HIIT protocol that we adopted is nonstandard; such protocols normally comprise of 10 exercise bouts, rather than eight, and the recovery periods are either of a 60-s or 75-s duration (Stork et al., 2017). In terms of the number of bouts, a nonstandard protocol was purposefully selected given that participants were required to visit the laboratory on four occasions, and we did not wish to render each visit highly unpleasant and thus run a risk of high participant attrition. In terms of the slightly extended recovery period, this was incorporated to allow sufficient scope for bodily pulses to entrain with the rhythmical qualities of the respite–active music selections (e.g., Khalfa, Roy, Rainville, Dalla Bella, & Peretz, 2008). Each participant was scheduled at the same time of day for their experimental and control trials in order to reduce diurnal variation in HIIT performance (see e.g., Atkinson & Reilly, 1996).

The participant was prompted to report RPE, state attention, FS, and FAS in the last 15 s of each of the eight bouts of high-intensity exercise and in the last 15 s of each recovery period. Perceived enjoyment and remembered pleasure were reported immediately following cool-down and 5 min postexercise. At the end of laboratory visit #4, each participant was asked two open-ended questions as a form of manipulation check to evaluate their perception of differences in the audio content between the two experimental conditions. It is important within such protocols that differences in music tempi across conditions are discernible given that, in real-world conditions, exercisers are able to decide upon just how stimulating or energizing a music program will be (Karageorghis & Jones, 2014). Each participant was also administered a music liking item (see Karageorghis & Jones, 2014) to gauge whether there were differences between the music programs used in each of the two experimental conditions.

Music Choice and Delivery

Respite-active music was played by use of a cellphone and Bluetooth speaker (Libratone Zipp Mini 2; Libratone, Nordhavn, Denmark; to enable verbal interaction between the participant and experimenters) at a sound intensity of 70 dBA for the entire 90-s recovery period following each bout of exercise. There was no music playing during the warm-up or each high-intensity exercise bout. The music tracks were selected by the experimenters based on the criteria outlined by Karageorghis et al. (2006) and with reference to the Karageorghis (2016) theoretical model pertaining to music selection in the domain of exercise and sport. Each participant was administered a contemporary pop-music playlist in the two experimental conditions. The playlist for each experimental condition was developed by the experimenters with reference to the aforementioned tempo criteria but entailed the use of a selection panel comprised of participants who were not involved in the experimental phase of the study. The panel ($N = 6$; three women and three men) had a similar sociocultural background and were in the same age range as the experimental participants (see Karageorghis & Terry, 1997). These playlists were 12 min in length to match the total duration of the recovery sessions and were rated by use of the Brunel Music Rating Inventory-3 (Karageorghis & Terry, 2011) to ensure they were invariant in terms of their motivational qualities (the two playlists can be viewed in Supplementary File 1).

Data Analysis

Following data screening and checks for the relevant parametric assumptions, differences in theoretically linked dependent variables (e.g., affect and arousal) measured over time were analyzed by use of mixed-model 3 (Condition) × 8 (Time) MANOVAs. Differences in remembered pleasure and exercise enjoyment were analyzed by use of oneway, RM ANOVAs. Maximal HR was calculated using the Gellish et al. (2007) formula and percentage of maximal heart rate was calculated for the exercise bouts and associated recovery periods. Analysis of HR data was conducted by means of 3 (Condition) × 8 (Time) ANOVAs. In all ANOVAs and MANOVAs, Greenhouse–Geisser-corrected *F* values were used in the case of sphericity violations and pairwise comparisons were subject to Bonferroni adjustment. Music liking differences were analyzed using a paired-samples *t* test.

Results

Data Diagnostics

Data screening revealed 51 univariate outliers of which 45 were accounted for by one case that was deleted prior to the analyses. The remaining six outliers, all associated with HR measures, were adjusted until they came within the range $z \pm 3.29$ (see Tabachnick & Fidell, 2018). Normality tests indicated that HR, in particular, exhibited instances of non-normality (negative skewness) and square root transformations were applied but did not entirely remedy the non-normality; accordingly, the non-normalized data were retained for analysis. To aid interpretation of the results presented herein, descriptive statistics for all dependent measures, across conditions and throughout the HIIT protocol, are provided in Table 1.

In-Task Psychological Variables

The 3 (Condition) × 8 (Stage) MANOVA for RPE and state attention at the end of the exercise bouts indicated significant omnibus statistics, Pillai's Trace = 0.19, $F(28, 616) = 2.26$, $p < .001$, $\eta_p^2 = .93$. Stepdown *F* tests indicated a significant interaction effect for RPE (see Table 2). Examination of standard errors ($\pm$ 2 *SE*) showed differences from Stage 5 onwards between medium-tempo music and control (see Figure 1), with medium-tempo music yielding lower RPE. Differences also emerged between medium- and fast-tempo music at Stage 5 and Stage 8 (medium < fast). The twoway interaction for state attention was nonsignificant (see Table 2 and Figure 2).

A main effect of condition emerged for RPE (see Table 2) with pairwise comparisons indicating differences between control and medium-tempo music (control > medium), and between medium- and fast-tempo music (medium < fast; see Figure 1). Also, a main effect of stage emerged for RPE (see Table 2), with pairwise comparisons indicating differences between the early and late stages of HIIT (see Figure 1). Only a main effect of stage emerged for state attention (see Table 2), with pairwise comparisons indicating differences between the early and late stages of HIIT (see Figure 2).

The 3 (Condition) × 8 (Stage) MANOVA for RPE and state attention at the end of the recovery period indicated significant omnibus statistics (Pillai's Trace = 0.17, $F(28, 616) = 2.09$, $p < .001$; $\eta_p^2 = .09$). Stepdown F tests indicated a significant interaction effect for RPE (see Table 2). Examination of standard errors showed differences from Stage 5 onwards between control and medium-tempo music, with the latter yielding lower RPE. There were also differences between medium- and fast-tempo music from Stages 6–8 (medium < fast; see Figure 1). The twoway interaction for state attention was nonsignificant (see Table 2 and Figure 2).

A main effect of condition emerged for RPE with pairwise comparisons indicating differences between control and medium-tempo music (control > medium), as well as between medium- and fast-tempo music (medium < fast; see Table 2). Also, a main effect of stage emerged for RPE with pairwise comparisons indicating differences between the early and late stages of HIIT (see Table 2 and Figure 1). A main effect of condition also emerged for state attention (Table 2), with pairwise comparisons indicating differences between control and both music conditions; the latter yielded higher dissociation scores (see Figure 2). A main effect of stage emerged for state attention (see Table 2), with pairwise comparisons indicating differences between the early and late stages of HIIT (i.e., association increased through the HIIT stages; see Figure 2).

In-Task Affective Measures

The 3 (Condition) × 8 (Stage) MANOVA for affective measures (valence and arousal) at the end of the exercise bouts indicated significant omnibus statistics, Pillai's Trace = 0.24, $F(28, 616) = 3.00$, $p < .001$, $\eta_p^2 = .12$, and stepdown F tests indicated a significant interaction effect for arousal (see Table 2). Examination of standard errors showed differences at Stage 2 between medium-tempo music and control (medium < control), and at Stage 8 between fast-tempo music and control (fast > control; see Figure 3). The twoway interaction for affective valence was nonsignificant (see Table 2 and Figure 3).

There was a main effect of condition for affective measures (valence and arousal) at the end of the exercise bouts, Pillai's Trace = 0.46, $F(4,88) = 6.65$, $p < .001$, $\eta_p^2 = .23$. Stepdown F tests indicated a significant effect only for affective valence (see Table 2), with pairwise comparisons showing differences between medium-tempo music and control (medium > control), medium-tempo music and fast-tempo music (medium > fast), and fast-tempo music and control (fast > control; see Figure 3). There was also a main effect of stage, Pillai's Trace = 1.02, $F(14, 308) = 22.70$, $p < .001$, $\eta_p^2 = .51$. Stepdown F tests indicated a significant effect for affective valence (see Table 2), with pairwise comparisons showing a gradual decline through the stages (see Figure 3). Stepdown F tests indicated a significant effect for arousal (see Table 2), with pairwise comparisons showing a gradual increase through the stages (see Figure 3).

The 3 (Condition) × 8 (Stage) MANOVA for affective measures (valence and arousal) at the end of the recovery period yielded significant omnibus statistics, Pillai's Trace = 0.14, $F(28, 616) = 1.69$, $p = .015$, $\eta_p^2 = .07$. Stepdown F tests indicated a significant twoway interaction effect for arousal (see Table 2). Examination of standard errors showed differences at Stage 1 between fast-tempo music and control (fast < control), and at Stage 6 between fast-tempo music and control (fast > control; see Figure 3). The twoway interaction for affective valence was nonsignificant (see Table 2 and Figure 3).

There was a main effect of condition for affective measures (valence and arousal) at the end of the recovery period, Pillai's Trace = 0.51, $F(4, 88) = 7.54$, $p < .001$, $\eta_p^2 = .26$). Step down F tests indicated a significant effect only for affective valence (see Table 2), with pairwise comparisons showing differences between medium-tempo music and control (medium > control), and medium-tempo and fast-tempo music (medium > fast; see Figure 3). There was also a main effect of stage, Pillai's Trace = 0.88, $F(14, 308) = 17.35$, $p < .001$, $\eta_p^2 = .44$). Stepdown F tests indicated a significant effect for affective valence (see Table 2), with pairwise comparisons showing a gradual decline through the stages (see Figure 3). Stepdown F tests indicated a significant effect for arousal (see Table 2), with pairwise comparisons showing an increase between the early and late stages of HIIT (see Figure 3).

Heart Rate

The 3 (Condition) × 8 (Stage) ANOVA for average HR during the exercise bouts was significant (see Table 2), with an examination of standard errors showing a difference between medium-tempo music and control (medium > control), only at Stage 1. There was a main effect of condition; albeit no significant differences emerged in the ensuing pairwise comparisons (see Table 2). There was a main effect of stage (see Table 2), with pairwise comparisons showing a gradual increase in HR through the stages (see Table 1). The 3 (Condition) × 8 (Stage) ANOVA for peak HR during the exercise bouts was nonsignificant, as was the main effect of condition (see Table 2). A main effect of stage emerged, with pairwise comparisons showing differences from Stages 1–8 (i.e., see Table 1 and Table 2).

The 3 (Condition) × 8 (Stage) ANOVA for average HR during the recovery periods was significant (see Table 2), with an examination of standard errors showing that at Stages 4–5, there was a difference between fast-tempo music and control (fast < control). There was no main effect of condition; however, there was a main effect of stage, with pairwise comparisons showing a gradual increase in HR through to Stage 7 (see Table 2). The 3 (Condition) × 8 (Stage) ANOVA for lowest recorded HR during the recovery periods was significant (see Table 2). Examination of standard errors showed differences between control and fast-tempo music at Stage 4 and Stage 5 (control > fast tempo). There was a main effect of condition; albeit pairwise comparisons showed no significant differences (see Table 2). There was also a main effect of stage, with pairwise comparisons indicating differences among all stages through to Stage 7 (i.e., lowest recorded HR increased throughout; see Table 2).

Post-Task Psychological Measures

The RM ANOVA for exercise enjoyment (PACES) was significant. Pairwise comparisons showed differences across all conditions, with medium-tempo music eliciting the highest scores followed by fast-tempo and control (see Table 2). The RM ANOVA for remembered pleasure was significant, with pairwise comparisons showing that medium-tempo music elicited higher scores than control, as did fast-tempo music (see Table 2).

Music Liking

The t test for the music liking scores between the medium-tempo (M = 5.92, SD = 0.63) and fast-tempo (M = 5.58, SD = 0.75) music conditions showed that there was no significant difference, $t(22) = 2.05$, p = .052.

Manipulation Check

Responses from the open-ended questions indicated that 23 participants were cognizant that one music condition was faster than the other.

Discussion

The main purpose of the study was to investigate the effects of respite–active music on psychological and psychophysiological responses both during and immediately after an eight-stage HIIT protocol. In regard to H_1, it appears that medium-tempo music was generally superior during recovery periods in terms of psychological outcomes (higher affective valence/enjoyment/pleasure scores, and lower RPE), with the exception of state attention in which dissociation scores were similar across the two music conditions (see Figure 2), and so it is partially accepted. With reference to H_2, which related to recovery HR, there was no clear differentiation across conditions and so it is not accepted. It is notable, however, that a main effect of condition was identified, albeit this was not associated with significant pairwise comparisons (see Table 2). H_3 is accepted, as there was no Condition × Time interaction for either average or peak HR in the exercise bouts. H_4 concerned the expected lack of effect of the music manipulation on exercise bout-related measures and was only partially accepted, given that medium-tempo music elicited lower RPE scores as the HIIT stages progressed (see Table 2 and Figure 1).

In-Task Psychological Measures

The core affect data show how the medium-tempo condition assuaged the inevitable displeasure that is experienced in the latter stages of both the exercise bouts and recovery periods of HIIT. This concurs with the findings of recent related studies (Eliakim et al., 2012; Hutchinson & O'Neil, 2020) and it is clear that the effects of music were seemingly more potent as fatigue levels increased. Recent mechanistic work suggests that the presence of music inhibits communication across somatosensory regions of the brain during cycle ergometer exercise (Bigliassi, Karageorghis, Wright, Orgs, & Nowicky, 2017). Such dulling of afferent signals might account for the affective benefits that emerged in the present study (see Figure 3).

An interesting and somewhat unexpected finding to emerge from the RPE data is that, from Stage 4, there is a marked reduction in RPE at the end of the exercise bouts with medium-tempo music, compared to the other two conditions (see Figure 1). This hints at a cumulative carryover effect of the medium-tempo music that was delivered during the recovery periods. The presence of a carryover effect counters what Crust (2004) reported when examining carryover effects of music in an isometric strength task. The strength test to failure required high effort and participants experienced localized muscle fatigue in a manner akin to HIIT protocols. Albeit Crust (2004) reported ergogenic effects of music *during* the task, music exposure *prior* to the task did not have any such effects. In the present study, there seemed to be some carryover effects of respite–active music on perceptions of exertion during exercise bouts (see Figure 1).

The aforementioned differences in RPE were not, however, matched in state attention for the exercise bouts; there was no differentiation between the two music conditions, both of which yielded higher scores for association than control in the recovery periods (see Table 1 and Figure 2). It is noteworthy that the present findings are indicative of the notion that RPE and state attention are not phenomenologically isomorphic (Razon, Hutchinson, & Tenenbaum, 2012).

Heart Rate (HR) Data

The main effect of condition for recovery low HR was significant but the associated pairwise comparisons did not exhibit any differences (see Table 2). There was an anomaly evident in this subset of the data given that, overall, fast-tempo music elicited slightly lower HRs (see Table 1). As expected, HR data indicated that physiological workload increased as the HIIT session progressed. The interaction effects identified in the average HR during exercise bouts, and during recovery periods, do not point to any sort of meaningful trend, owing to the rather sporadic nature of such differences.

Given that the application of respite–active music had no bearing on the three HR indices, we can deduce that, from a physiological arousal perspective, there is no potential adverse effect on bouts of high-intensity exercise. This point holds both for medium-tempo and fast-tempo music (see also Jones et al., 2017). Nonetheless, the medium-tempo music did engender some psychological benefits and such benefits in recovery did not appear to prompt participants to exert less effort—in physiological terms—during subsequent exercise bouts (see Table 1 and Table 2). This finding suggests that respite–active music of a tempo $\geq$ 120 bpm can facilitate active recovery without inhibiting subsequent effort exertion.

The lack of a main effect of condition contrasts with the recent findings of

Karageorghis et al. (2018). It could be that the expected differences in HR recovery might only be evident following longer exposure to music in the context of either high-intensity or exhaustive exercise. Longer exposure to a musical work renders the entrainment process more likely and so, the use of musical excerpts, rather than entire musical works, may have precluded HR entrainment (see Terry et al., 2020). Nonetheless, in the context of HIIT recovery, the use of entire musical works is not possible, unless such works are of very short duration.

Post-Task Psychological Measures

The results for exercise enjoyment, as measured by PACES (see Table 2), provided the most defined differentiation across conditions. The medium-tempo music yielded the highest scores, which suggests that in terms of a gestalt assessment of the HIIT experience, such music is superior to both fast-tempo music and a no-music control. Similarly, remembered pleasure showed medium-tempo music to be superior to control but, in this instance, differences between music conditions did not emerge. Exercise practitioners might consider either type of music (i.e., medium or fast tempo) with a view to enhancing people's recall of high-intensity exercise (see Hutchinson & O'Neil, 2019; Jones et al., 2017). Notably, fast-tempo music administered across the entire course of an interval-type session (including exercise bouts and recovery periods) has also been shown to enhance enjoyment compared to a no-music control condition (Stork et al., 2019).

Strengths and Limitations

There have been over 300 published studies that examined pretask and in-task music applications in exercise or sport, but only a handful that have examined post-task applications (see Terry et al., 2020). This study is the first to empirically examine the relevance of music tempo during the application of respite–active music and provides insight into how the benefits of this mode of music application can be maximized. A postexperiment manipulation check indicated that 23 out of 24 participants were able to identify that there were tempo differences between the two music conditions. This is a strength given that participants correctly perceived the independent variable manipulation, which allows more accurate conclusions to be drawn in regard to how the manipulation influenced the dependent variables (Thomas, Nelson, & Silverman, 2015). Moreover, as the check took place at the end of all experimental trials, it could not influence participants' responses or cognitions (e.g., via an experimenter effect) during the trials.

The affective responses to exercise evident in healthy and recreationally active participants, such as those tested in the present study, differ from obese and inactive individuals (see e.g., Decker & Ekkekakis, 2017). The applicability of the present data is limited to active/healthy populations. Accordingly, further examination of respite–active music with at-risk populations (e.g., obese, type 2 diabetics) and people who are insufficiently active, appears warranted. The inclusion criterion pertaining to the recruitment only of young adults precludes the generalization of the present findings to other subgroups of the population for which the effects of medium-tempo music might be different. Previous research examining music preferences in an exercise context has detailed how music-tempo preferences vary in accord with age (e.g., Priest & Karageorghis, 2008).

Respite music is an atypical music application and would require considerable planning and track editing for a playlist to contour the demands of an exercise or training session (Karageorghis, 2017). The present data indicate some utility in the adoption of playlists to match the peaks and troughs of a HIIT session with a view to positively influencing psychological responses. Note that the atypical nature of the present application of music led to the selection of a recovery period (90 s) that was longer than the typical recovery period associated with HIIT protocols (60–75 s; see e.g., Little, Safdar, Wilkin, Tarnopolsky, & Gibala, 2010). This slightly extended recovery was adopted to give the respite–active music sufficient time to take effect, but the use of brief musical excerpts (e.g., 60 s) may not be as efficacious as the 90-s excerpts used in the present study. Moreover, the tempo-related recommendations presented herein should only be considered for HIIT protocols that include active recovery periods. Passive recovery is integral to many HIIT protocols and further research to examine possible differences in terms of optimal music-tempo prescription appears warranted.

Attitudes toward HIIT (see e.g., Stork & Martin Ginis, 2017) were not assessed before and after the experiment, and thus might be considered for inclusion by future investigators. Similarly, HR was not measured as a manipulation check during the baseline test and future researchers might combine physiological measures with Wmax. A further measurement-related limitation is that the affect measures taken at the end of the exercise bouts and recovery periods (FS and FAS) were not also taken prior to the start of each test protocol. Such measures might have been useful in gauging participants' pretask affective state and whether this had any bearing on subsequent psychological and psychophysiological outcomes. Nonetheless, the use of a within-subjects design to reduce the influence of between-subjects error (see Tabachnick & Fidell, 2018), served to assuage any potential threat to internal validity posed by pretask affective state. The order reversal of the four single-item scales (RPE, state attention, FS, and FAS) for the recovery period may have affected participant responses to a small degree (e.g., through temporal differences vis-à-vis the exercise bout administration). It should be stressed, however, that the order reversal was undertaken to mitigate response order effects.

As expected, a significant difference for liking scores did not emerge between the two music conditions; nonetheless, the medium-tempo music program attracted slightly higher scores than its fast-tempo counterpart ($M_{\text{diff.}} = 0.34$). Such aesthetic differences between medium-tempo and fast-tempo are well documented in the psychomusicological literature (e.g., Berlyne, 1971) and music-in-exercise literature (e.g., Karageorghis et al., 2011). Reasons advanced for the difference include people's general familiarity with medium tempi, as most popular pieces are recorded in the medium-tempo range (i.e., 100–125 bpm), and the ease with which musical works at medium tempi can be processed by the human brain.

Implications for Practice

Over the last decade, a vibrant debate has raged in exercise psychology regarding the displeasure associated with high-intensity exercise regimens such as HIIT, and whether promotion of such regimens might be counterproductive from a public health perspective (see e.g., Ekkekakis, Hartman, & Ladwig, 2020). The present findings do not, by any means, suggest that music-related applications represent a "magic bullet" in countering sedentary lifestyles. What is clear, however, is that judicious application of music to active recovery enhances pleasure and reduces perceived exertion. Accordingly, practitioners should consider coordinating interval-type exercise sessions with an emphasis on musical accompaniment for recovery. Whether the benefits reported herein would accrue with shorter musical excerpts (e.g., 60 s) is presently unknown and so future work could explore the minimum exposure time required for respite–active music to be efficacious.

On balance, medium-tempo music appears to yield the most benefits when used in between high-intensity exercise bouts and it should be noted that slow-tempo music can have a detrimental effect on subsequent anaerobic performance (see e.g., Hutchinson & O'Neil, 2020). Individual exercisers might consider editing playlists, using freely available software (e.g., Audacity), for HIIT sessions that include epochs of music and silence to match their desired HIIT protocol. If the efficacy of this type of music application is established, an algorithm could be developed that creates playlists that are punctuated by periods of silence to coincide with exercise bouts.

Conclusions and Recommendations

Medium-tempo respite–active music showed the greatest capacity to influence psychological responses both during and after a HIIT session. Notably, perceptions of exertion during the exercise bouts (when no music was played) *and* recovery periods in the latter stages of a HIIT session appeared to be reduced through the use of medium-tempo respite–active music when compared to a no-music control. Nonetheless, the present data clearly indicate that a decline in pleasure (i.e., exercise-related affect) is inevitable during HIIT-type protocols but music used during recovery periods can make the session seem less unpleasant. There is a need for such interventions to be studied in longitudinal studies to further understanding of how in-session manipulation of the exercise experience influences adherence in the *longue durée*. Respite–active music offers a novel music application that is inexpensive and might be considered by practitioners seeking to improve affective responses to HIIT sessions.

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Table 1

Descriptive Statistics (M [SD]) for Dependent Measures Across Conditions for Exercise Bouts (E) and Recovery Periods (R) Through Eight Stages of HIIT

		Condition		
	Stage	Control	Medium tempo	Fast tempo
RPE				
	E1	3.74 (1.63)	3.96 (1.15)	3.52 (1.16)
	R1	3.61 (1.62)	2.39 (0.89)	3.13 (1.22)
	E2	5.13 (1.36)	4.87 (1.22)	4.52 (1.08)
	R2	3.78 (1.13)	3.04 (0.93)	3.17 (0.89)
	E3	5.65 (1.23)	4.91 (1.00)	5.00 (1.24)
	R3	4.52 (1.12)	3.52 (0.99)	3.87 (0.82)
	E4	6.43 (1.27)	5.65 (1.07)	6.22 (0.95)
	R4	4.57 (1.04)	3.74 (1.18)	4.65 (0.94)
	E5	6.74 (0.86)	5.17 (1.40)	6.43 (0.95)
	R5	5.35 (1.11)	4.26 (0.86)	5.04 (1.15)
	E6	7.61 (1.27)	6.48 (1.16)	7.17 (1.40)
	R6	5.52 (1.28)	4.22 (1.24)	5.65 (1.34)
	E7	8.09 (1.20)	6.78 (1.13)	7.70 (1.22)
	R7	7.13 (1.33)	5.04 (1.11)	6.52 (1.24)
	E8	9.04 (0.88)	7.43 (1.08)	8.87 (1.10)
	R8	7.26 (1.63)	4.74 (1.74)	7.13 (1.60)
State Attention				
	E1	58.70 (17.66)	53.48 (15.84)	51.74 (15.57)
	R1	55.22 (16.20)	69.57 (15.52)	68.26 (14.66)
	E2	48.26 (17.23)	50.00 (11.28)	49.13 (15.35)
	R2	53.74 (15.83)	69.13 (10.84)	65.65 (19.03)
	E3	43.48 (11.52)	45.22 (9.94)	41.74 (14.35)
	R3	47.83 (17.57)	63.48 (11.52)	56.52 (15.55)
	E4	37.39 (14.21)	37.39 (12.51)	40.87 (11.64)
	R4	49.57 (16.37)	56.52 (12.29)	57.39 (16.02)
	E5	33.04 (13.63)	32.61 (11.76)	36.96 (13.63)
	R5	43.48 (13.69)	51.30 (13.92)	48.26 (16.42)
	E6	26.52 (12.29)	29.13 (10.41)	27.83 (10.43)
	R6	39.57 (15.52)	46.96 (17.17)	43.91 (14.06)
	E7	21.74 (9.84)	25.22 (12.01)	21.30 (10.58)
	R7	28.26 (11.54)	41.74 (15.86)	40.00 (15.95)
	E8	17.83 (8.51)	20.87 (9.96)	20.00 (12.79)
	R8	36.52 (18.24)	44.78 (15.04)	41.30 (20.74)
Feeling Scale				
	E1	1.26 (1.71)	2.57 (1.56)	1.48 (1.31)
	R1	1.39 (1.12)	2.09 (1.08)	1.74 (1.21)
	E2	0.57 (1.08)	1.57 (1.24)	0.7 (1.46)
	R2	1.17 (1.11)	1.91 (0.79)	1.26 (1.39)
	E3	-0.43 (1.41)	0.78 (0.90)	0.13 (1.29)
	R3	0.39 (0.94)	1.39 (1.12)	1 (1.24)
	E4	-1.04 (1.22)	0 (1.21)	-0.22 (1.20)
	R4	-0.17 (1.15)	1 (1.21)	0.22 (1.38)
	E5	-1.74 (1.01)	-0.13 (1.66)	-0.61 (0.99)
	R5	-1.04 (1.26)	0.43 (1.12)	-0.43 (1.41)

(continued)

Table 1 *(continued)*

	Stage	Condition		
		Control	Medium tempo	Fast tempo
	E6	-2.78 (0.90)	-0.74 (1.18)	-2.17 (1.44)
	R6	-1.57 (1.24)	0.04 (1.11)	-0.96 (1.40)
	E7	-2.78 (1.13)	-1.57 (1.04)	-2.04 (1.55)
	R7	-2.48 (1.04)	-0.61 (1.23)	-1.91 (1.51)
	E8	-3.43 (1.08)	-2.17 (1.50)	-2.78 (1.35)
	R8	-2.13 (1.69)	-1.17 (1.72)	-1.65 (1.72)
Felt Arousal Scale				
	E1	2.30 (1.11)	2.13 (0.97)	1.96 (0.88)
	R1	3.30 (0.97)	2.61 (0.58)	2.48 (0.90)
	E2	3.78 (1.41)	2.65 (0.83)	3.04 (1.11)
	R2	2.96 (0.71)	2.83 (0.83)	2.87 (1.01)
	E3	3.43 (0.95)	3.48 (1.16)	2.87 (1.06)
	R3	3.00 (1.00)	2.96 (0.64)	2.83 (0.89)
	E4	3.35 (1.15)	3.39 (0.84)	3.17 (0.83)
	R4	2.87 (1.22)	3.26 (0.81)	3.22 (0.74)
	E5	3.87 (1.18)	3.65 (0.89)	3.39 (1.16)
	R5	3.26 (1.21)	3.35 (0.89)	3.48 (0.67)
	E6	3.65 (1.53)	3.57 (1.08)	4.35 (0.78)
	R6	3.39 (1.16)	3.83 (0.65)	4.35 (0.94)
	E7	4.04 (1.43)	4.39 (1.08)	4.83 (0.98)
	R7	3.65 (1.34)	3.96 (0.88)	4.13 (0.92)
	E8	4.00 (1.17)	4.78 (0.95)	4.91 (0.67)
	R8	3.57 (1.27)	3.52 (1.16)	3.78 (1.09)
Heart Rate (%max)				
	E1	67.77 (4.44)	74.02 (4.20)	70.69 (6.14)
	R1	69.90 (6.12)	71.44 (3.14)	73.04 (7.19)
	E2	77.75 (4.82)	77.27 (3.17)	76.72 (6.36)
	R2	77.84 (4.97)	76.92 (2.87)	74.87 (6.05)
	E3	83.07 (3.59)	82.11 (3.30)	78.90 (5.69)
	R3	81.89 (4.70)	80.10 (3.03)	78.35 (6.38)
	E4	85.31 (4.19)	84.38 (3.41)	81.25 (5.81)
	R4	85.70 (4.58)	83.45 (2.71)	80.80 (6.65)
	E5	87.67 (4.12)	86.40 (3.52)	84.21 (6.78)
	R5	87.85 (4.00)	85.45 (3.36)	82.67 (6.87)
	E6	90.27 (3.86)	88.86 (3.73)	85.32 (7.29)
	R6	89.62 (4.94)	88.37 (3.73)	85.39 (7.80)
	E7	92.09 (4.36)	91.41 (4.70)	89.49 (6.56)
	R7	91.98 (4.54)	91.75 (4.40)	89.47 (6.56)
	E8	95.33 (4.71)	95.08 (5.00)	92.50 (7.31)
	R8	91.68 (4.38)	91.11 (3.65)	89.92 (8.73)
PACES		60.43 (3.87)	78.13 (6.98)	68.96 (5.09)
Remembered Pleasure		-23.91 (31.15)	13.04 (28.03)	0.87 (29.22)

Table 2

Inferential Statistics for Analyses on Psychological and Psychophysiological Measures

	F	*df*	*p*	η_p^2	Source of Difference
RPE (E)					
Condition × Stage	3.49	6.68, 146.96	.002	.14	Medium < Control from Stage 5 onward; Medium < Fast at Stage 5 and 8
Condition	12.40	2, 88	< .001	.36	Control > Medium; Medium < Fast
Stage	151.82	7, 308	< .001	.87	Stage 1–4 < Stage 5–8
RPE (R)					
Condition × Stage	3.61	6.92, 152.23	< .001	.14	Medium < Control from Stage 5 onward; Medium < Fast Stage 6–8
Condition	31.00	2, 88	< .001	.59	Control > Medium; Medium < Fast
Stage	80.20	4.47, 98.29	< .001	.79	Incr. from Stage 1–8
State Attention (E)					
Condition × Stage	1.09	6.53, 143.61	.374	.047	—
Condition	.102	2, 154	.903	.005	—
Stage	69.14	3.58, 143.61	< .001	.76	Decr. from Stage 1–8
State Attention (R)					
Condition × Stage	.70	14, 308	.770	.31	—
Condition	11.34	11.34, 35.11	< .001	.34	Control < Medium, Fast
Stage	39.24	3.97, 87.22	< .001	.64	Decr. from Stage 2–5; Decr. from Stage 6–8
Feeling Scale (E)					
Condition × Stage	1.37	6.02, 142.18	.231	.06	—
Condition	18.60	2, 44	< .001	.46	Medium > Control, Fast; Fast > Control
Stage	135.17	4.03, 88.69	< .001	.86	Decr. from Stage 1–4; Decr. from Stage 5–8
Feeling Scale (R)					
Condition × Stage	1.22	6.78, 149.13	.294	.05	—
Condition	20.28	2, 44	< .001	.48	Medium > Control, Fast
Stage	86.91	7, 154	< .001	.80	Decr. from Stage 1–7
Felt Arousal Scale (E)					
Condition × Stage	4.75	14, 308	< .001	.18	Medium < Control at Stage 2; Fast > Control at Stage 8
Condition	.152	2, 44	.859	.007	—
Stage	49.78	3.98, 88.69	< .001	.69	Incr. from Stage 1–7

(continued)

Table 2 *(continued)*

	F	*df*	*p*	η_p^2	Source of Difference
Felt Arousal Scale (R)					
Condition × Stage	2.21	14, 308	.007	.09	Fast < Control at Stage 1; Fast > Control at Stage 6
Condition	.550	2, 44	.581	.024	—
Stage	16.11	7, 154	< .001	.42	Incr. between Stages 1 and 3; Incr. between Stages 6 and 8
Heart Rate Average (%max; E)					
Condition × Stage	9.87	3.69, 81.28	< .001	.31	Medium > Control at Stage 1
Condition	4.62	1.53, 33.69	.25	.17	—
Stage	300.50	1.97, 43.43	< .001	.93	Incr. from Stage 1–8
Heart Rate Average (%max; R)					
Condition × Stage	6.63	3.94, 86.70	< .001	.23	Fast < Control at Stages 4–5
Condition	3.63	1.46, 32.04	.051	.14	—
Stage	187.13	1.42, 31.31	< .001	.90	Incr. from Stage 1–7
Heart Rate Peak (%max; E)					
Condition × Stage	1.92	5.10, 112.27	.095	.08	—
Condition	1.61	1.43, 31.52	.217	.07	—
Stage	303.21	2.33, 51.36	< .001	.93	Incr. from Stage 1–7
Heart Rate Low (%max; R)					
Condition × Stage	244.16	4.10, 90.13	< .001	.08	Control > Fast at Stage 4–5
Condition	3.72	2, 44	.032	.15	—
Stage	256.98	1.44, 31.73	< .001	.92	Incr. from Stage 1–7
PACES	14.62	2, 44	< .001	.79	Medium > Control, Fast; Fast > Control
Remembered Pleasure	14.62	1.52, 33.35	< .001	.40	Medium > Control; Fast > Control

Note. E = Exercise bout, R = Recovery bout, Incr = Increase, Decr = Decrease.

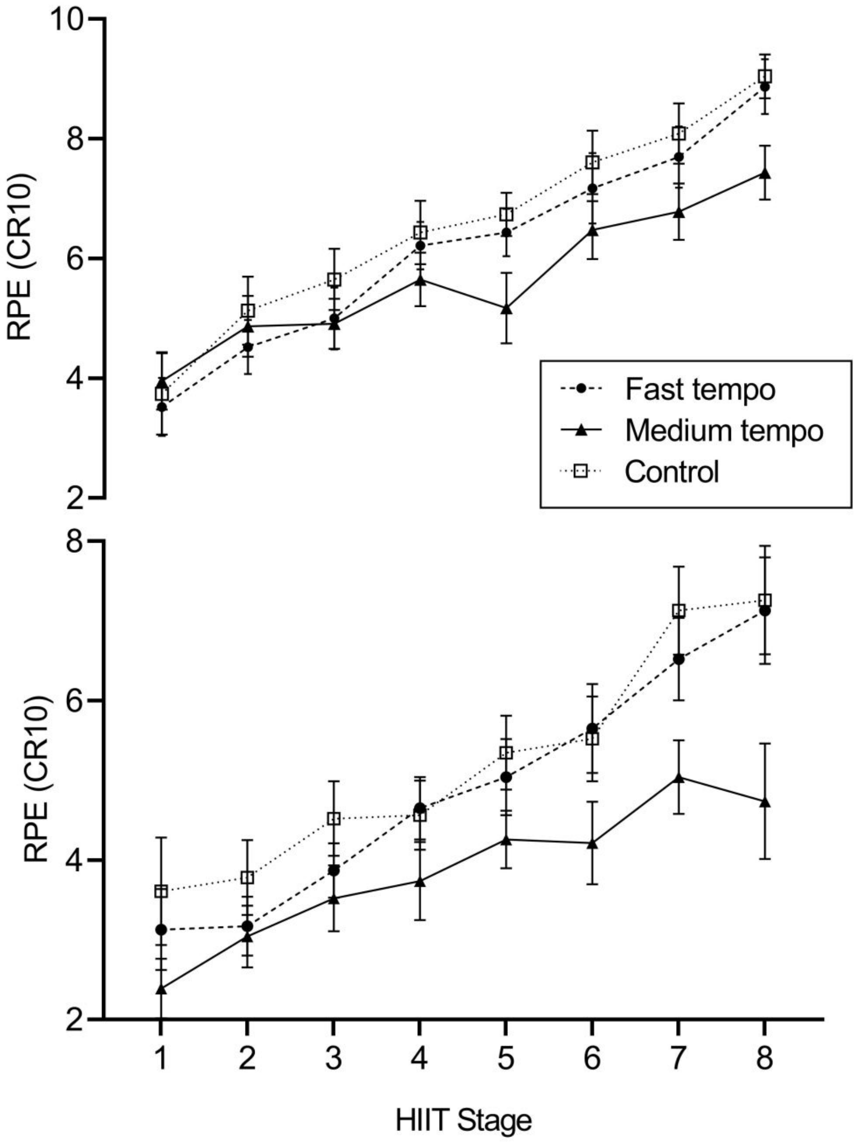

Figure 1. RPE responses across conditions during HIIT exercise bouts (top) and recovery periods (bottom). T-bars denote ± 2 standard errors.

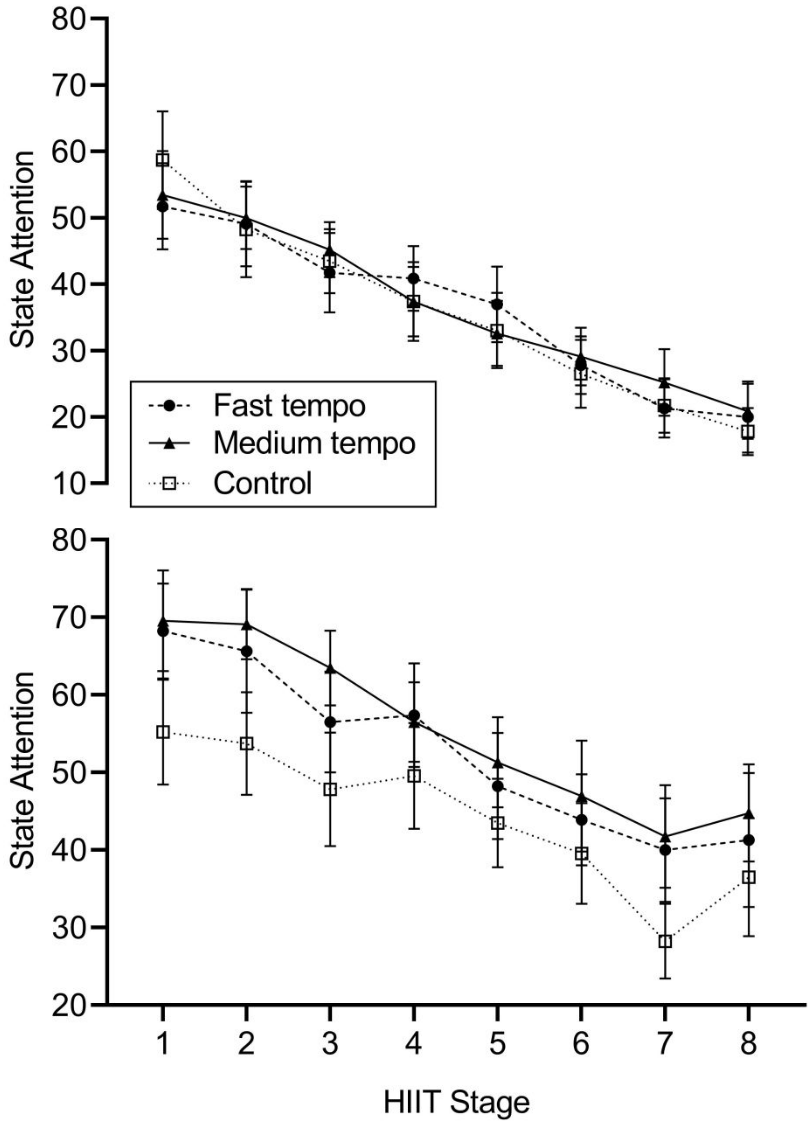

Figure 2. State attention responses across conditions during HIIT exercise bouts (top) and recovery periods (bottom). T-bars denote ± 2 standard errors.

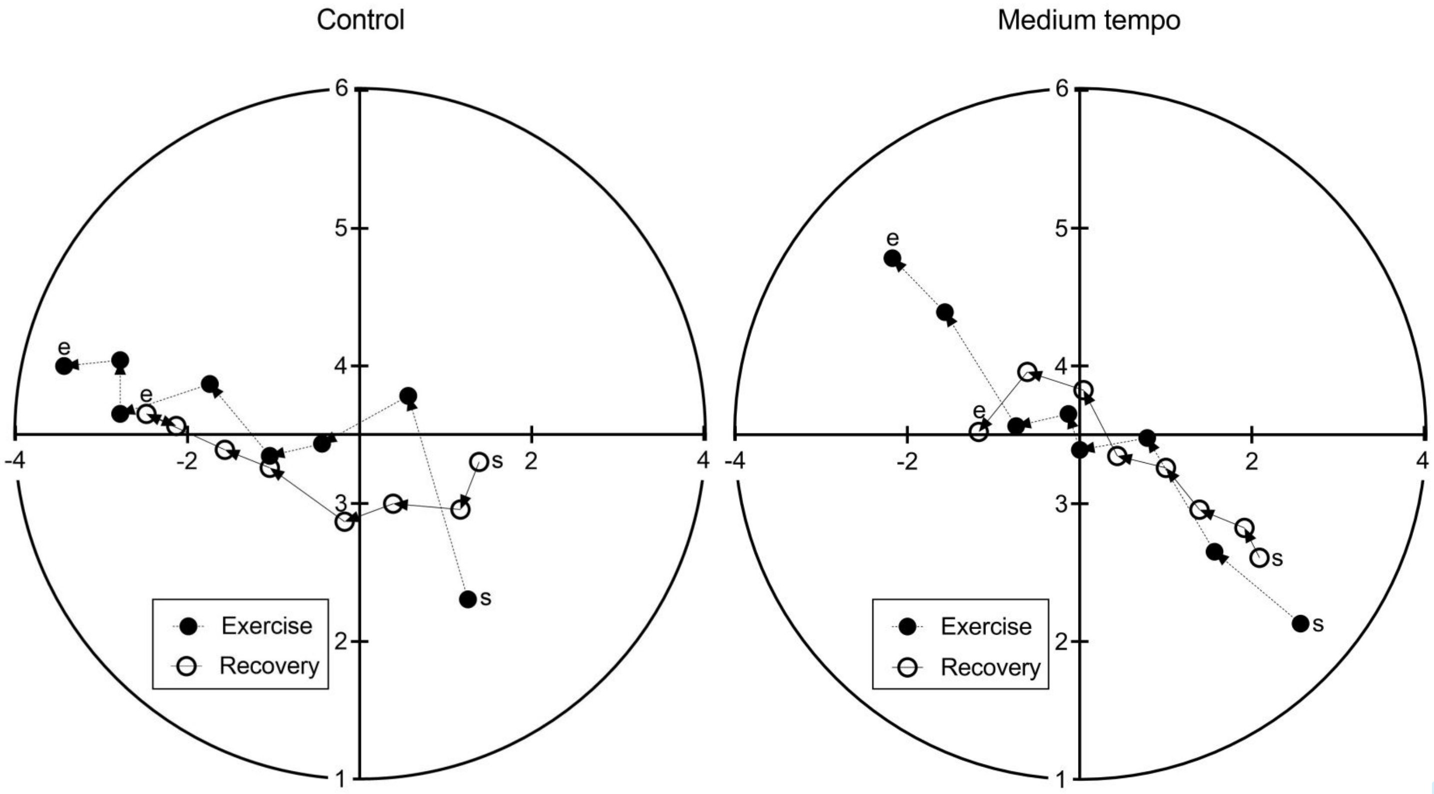

Figure 3. Feeling Scale (*x*-axis) and Felt Arousal Scale (*y*-axis) scores plotted on the Circumplex Model of Affect for three conditions. The arrows denote the "affective journey" through the eight stages of the HIIT protocol. The first stage is indicated with an "s" and the final stage with an "e".

Supplementary Table 1

Track Lists for Experimental Conditions

Artist	Track Name	HIIT Recovery Period
Medium-tempo music (120–125 bpm)		
Mike Mago, Dragonette	Secret Stash	1
Nyte	Fall For You	2
Loud Luxury	Body	3
Otto Knows (ft. Lindsey Stirling and Alex Aris	Dying For You	4
Robin Shulz (ft. Erika Sirola)	Speechless	5
Jack Wins (ft. Amy Grace)	Forever Young	6
Sigala, Ella Eyre	Came Here For Love	7
Calvin Harris, Sam Smith	Promises	8
Fast-tempo music (135–140 bpm)		
Davey Asprey	Fallout	1
Gareth Emery, Emma Hewitt	Take Everything	2
Markus Schulz	Facedown	3
Paul van Dyk, Ronald van Gelderen (ft. Eric Lumiere)	Everyone Needs Love	4
Saad Ayub (ft. Christina Novelli)	The Only One (Uplifting Mix)	5
Superfitness	Feel This Moment	6
Superfitness	Havana Remix	7
Above & Beyond	Sun & Moon	8

Note. The tempo of Sun & Moon was digitally altered to 136 bpm.