

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

KARAGEORGHIS, Costas I., JONES, Leighton <<http://orcid.org/0000-0002-7899-4119>>, HOWARD, Luke W., THOMAS, Rhys M., MOULASHIS, Panayiotis and SANTICH, Sam J.

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

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7 Costas I. Karageorghis<sup>1</sup>, Leighton Jones<sup>2</sup>, Luke W. Howard<sup>1</sup>, Rhys M. Thomas<sup>1</sup>,  
8 Panayiotis Moulashis<sup>1</sup>, & Sam J. Santich<sup>3</sup>

9

10 <sup>1</sup>Department of Life Sciences, Brunel University London, UK

11 <sup>2</sup>Academy of Sport and Physical Activity, Sheffield Hallam University, UK

12 <sup>3</sup>Department of Exercise Science and Sports Studies, Springfield College, USA

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**Abstract**

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We investigated the effects of respite–active music (i.e., music used for active recovery in between high-intensity exercise bouts) on psychological and psychophysiological outcomes. Participants ( $N = 24$ ) made four laboratory visits for a habituation, medium- and fast-tempo music conditions, and a no-music control. A HIIT protocol comprising  $8 \times 60$ -s exercise bouts at 100%  $W_{max}$  with 90 s active recovery was administered. Measures were taken at the end of exercise bouts and recovery periods (RPE, state attention, core affect), then upon cessation of the protocol (enjoyment and remembered pleasure). Heart rate (HR) was measured throughout. Medium-tempo music enhanced affective valence during exercise and recovery, while both music conditions increased dissociation (only during recovery), enjoyment, and remembered pleasure relative to control. Medium-tempo music lowered RPE relative to control but the HR results were inconclusive. As predicted, medium-tempo music in particular, had a meaningful effect on a range of psychological outcomes.

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

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

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

21 High-intensity interval training (HIIT) is a short-duration form of exercise that entails  
22 a series of short, high-intensity efforts, punctuated by recovery periods (Stork, Banfield,  
23 Gibala, & Martin Ginis, 2017). Studies have shown that several weeks of HIIT can bring  
24 benefits to physical health that are analogous to those derived from the long-duration,  
25 aerobic-type exercise that is more commonly adopted by the general public (Batacan,  
26 Duncan, Dalbo, Tucker, & Fenning, 2017). Such health benefits can also be realized by at-

1 risk and diseased populations (Gibala et al., 2014; Quindry, Franklin, Chapman, Humphrey,  
2 & Mathis, 2019). Albeit there is a growing body of evidence showing the physiological  
3 benefits of HIIT, from a public health/adherence perspective, there is a significant  
4 shortcoming. It is widely acknowledged that people can find HIIT to be rather unpleasant; a  
5 factor that can undermine long-term participation in such activity (see e.g., Decker &  
6 Ekkekakis, 2017; Ekkekakis, 2020).

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

14         The last decade has seen the emergence of an extensive corpus of work addressing the  
15 effects of music during high-intensity exercise (e.g., Jones et al., 2017; Karageorghis et al.,  
16 2009; Karageorghis et al., 2018; Stork et al., 2015). In HIIT protocols, the use of  
17 environmental stimuli to enhance recovery or respite periods has yet to be investigated in a  
18 systematic manner and provides tantalizing opportunities for researchers in the realm of sport  
19 and exercise psychology.

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

1 and fast-tempo music on breathing and heart rates.

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

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

20 Based on findings from previous research (Eliakim, Bodner, Meckel, Nemet, &  
21 Eliakim, 2012; Hutchinson & O’Neil, 2019; Karageorghis & Jones, 2014), we hypothesized  
22 that recovery periods accompanied by medium-tempo, respite–active music (120–125 bpm)  
23 would be superior in terms of psychological (i.e., higher affective  
24 valence/enjoyment/pleasure scores and less association) and psychophysical (i.e., lower RPE)  
25 outcome measures when compared to fast-tempo, respite–active music (135–140 bpm), and a  
26 no-music control condition ( $H_1$ ). In accord with related literature pertaining to the application

1 of recuperative music following exhaustive exercise (Karageorghis et al., 2018), we expected  
 2 lower average heart rate and the lowest absolute heart rate in recovery periods accompanied  
 3 by medium-tempo music when compared to fast-tempo music and control conditions ( $H_2$ ).  
 4 We did not expect any differences among conditions in terms of average and peak heart rate  
 5 during the high-intensity exercise bouts and so the null hypothesis was tested ( $H_3$ ). We did  
 6 not expect the experimental manipulations—applied only to recovery periods—to have any  
 7 significant effect on measures taken at the end of the exercise bouts ( $H_4$ ).

## 8 Method

### 9 Study design and Power Analysis

10 A fully counterbalanced, within-subjects design was employed with one control  
 11 condition (no music) and two experimental conditions (medium-tempo and fast-tempo  
 12 music). Using a more conservative effect size than that derived from Jones et al. (2017;  $\eta_p^2 =$   
 13 0.08) owing to a more subtle tempo manipulation between experimental conditions, an *a*  
 14 *priori* power analysis using a small-to-medium effect size ( $\eta_p^2 = 0.05$ ), an alpha level of .05,  
 15 power at .8, indicated that a sample of 21 participants would be required to detect differences  
 16 in a twoway repeated-measures (RM) 3 (Condition)  $\times$  8 (Time [HIIT exercise bouts and  
 17 active recovery periods]) ANOVA of Feeling Scale scores (the primary outcome measure).  
 18 An additional three participants were recruited to guard against deletions due to outliers and  
 19 to enable full counterbalancing of conditions.

### 20 Participants

21 With institutional ethics approval, 24 participants (12 women and 12 men;  $M_{\text{age}} = 22.5$   
 22 years,  $SD = 1.7$  years;  $M_{\text{height}} = 175.3$  cm,  $SD = 9.5$  cm;  $M_{\text{mass}} = 80.7$  kg,  $SD = 12.6$  kg;  $M_{\text{weekly}}$   
 23 *vigorous activity* = 60 min,  $SD = 25.8$  min;  $M_{\text{weekly moderate activity}} = 130$  min;  $SD = 70.5$  min) were  
 24 recruited through word of mouth at a university in \_\_\_\_\_ and all provided written  
 25 informed consent. Participant inclusion criteria were that they: a) were aged 18–25 years; b)  
 26 could fully comprehend spoken and written English; c) were healthy; and d) participated in at

1 least 150 min/week of moderate physical activity (PA) and/or more than 75 min/week of  
2 vigorous PA over the previous 3 months (World Health Organization, 2010). Participants  
3 were of a similar age in order to limit the effects of age on music preference, thereby  
4 addressing a potential confound (Karageorghis & Terry, 1997). Similarly, participants were  
5 recruited in such a way that there was a degree of homogeneity in their weekly levels of  
6 physical activity. This is important given that physical activity status is known to influence  
7 affective responses to exercise (Magnan, Kwan, & Bryan, 2013).

## 8 **Procedures**

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

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



1           The participant was asked to report her/his rating of perceived exertion by use  
2 of the CR-10 RPE scale (Borg, 1998), state attention by use of the Attention Scale (Tammen,  
3 1996), pleasure by use of the Feeling Scale (Hardy & Rejeski, 1989), and perceived  
4 activation by use of the Felt Arousal Scale (Svebak & Murgatroyd, 1985) in the final 15 s of  
5 each 60-s high-intensity exercise bout and before commencement of any music. The same  
6 measures were administered in the final 15 s of each 90-s recovery period but in the reverse  
7 order to minimize common method variance. Remembered pleasure was assessed using a  
8 200-point scale (Zenko, Ekkekakis, & Ariely, 2016), which ranges from -100 (*very*  
9 *unpleasant*) to 100 (*very pleasant*) and 0 represents a neutral response. Enjoyment was  
10 measured using the Physical Activity Enjoyment Scale (PACES; Kendzierski & DeCarlo,  
11 1991); scores can range from 18 to 126, with 72 representing the midpoint and thus a neutral  
12 score. These scales were administered immediately following the exercise bout, once the  
13 participant had dismounted the cycle ergometer. At the end of the session, the participant was  
14 led through a warm-down and encouraged to ask any questions s/he might have.

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

1 included, each with an exercise bout and an ensuing recovery period. The stages were treated  
2 as distinct units for analytical purposes.

3         The HIIT session comprised a 4-min warm-up at 50 W followed immediately by the  
4 first 60-s exercise bout (100%  $W_{max}$ ) at 75–80 rpm. The exercise bout was followed by a  
5 90-s recovery period at 50 W wherein the participant continued to cycle at 65–70 rpm. A  
6 further seven exercise bouts were completed, each separated by a 90-s recovery period.  
7 Following the final exercise bout, the participant completed a 90-s recovery period at 50 W  
8 and then dismounted the cycle ergometer.

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

20         The participant was prompted to report RPE, state attention, FS, and FAS in the last  
21 15 s of each of the eight bouts of high-intensity exercise and in the last 15 s of each recovery  
22 period. Perceived enjoyment and remembered pleasure were reported immediately following  
23 cool-down and 5 min postexercise. At the end of laboratory visit #4, each participant was  
24 asked two open-ended questions as a form of manipulation check to evaluate their perception  
25 of differences in the audio content between the two experimental conditions. It is important  
26 within such protocols that differences in music tempi across conditions are discernible given

1 that, in real-world conditions, exercisers are able to decide upon just how stimulating or  
2 energizing a music program will be (Karageorghis & Jones, 2014). Each participant was also  
3 administered a music liking item (see Karageorghis & Jones, 2014) to gauge whether there  
4 were differences between the music programs used in each of the two experimental  
5 conditions.

## 6 **Music Choice and Delivery**

7         Respite-active music was played by use of a cellphone and Bluetooth speaker  
8 (Libratone Zipp Mini 2; Libratone, Nordhavn, Denmark; to enable verbal interaction between  
9 the participant and experimenters) at a sound intensity of 70 dBA for the entire 90-s recovery  
10 period following each bout of exercise. There was no music playing during the warm-up or  
11 each high-intensity exercise bout. The music tracks were selected by the experimenters based  
12 on the criteria outlined by Karageorghis et al. (2006) and with reference to the Karageorghis  
13 (2016) theoretical model pertaining to music selection in the domain of exercise and sport.  
14 Each participant was administered a contemporary pop-music playlist in the two  
15 experimental conditions. The playlist for each experimental condition was developed by the  
16 experimenters with reference to the aforementioned tempo criteria but entailed the use of a  
17 selection panel comprised of participants who were not involved in the experimental phase of  
18 the study. The panel ( $N = 6$ ; three women and three men) had a similar sociocultural  
19 background and were in the same age range as the experimental participants (see  
20 Karageorghis & Terry, 1997). These playlists were 12 min in length to match the total  
21 duration of the recovery sessions and were rated by use of the Brunel Music Rating  
22 Inventory-3 (Karageorghis & Terry, 2011) to ensure they were invariant in terms of their  
23 motivational qualities (the two playlists can be viewed in Supplementary File 1).

## 24 **Data Analysis**

25         Following data screening and checks for the relevant parametric assumptions,  
26 differences in theoretically linked dependent variables (e.g., affect and arousal) measured

1 over time were analyzed by use of mixed-model 3 (Condition)  $\times$  8 (Time) MANOVAs.  
2 Differences in remembered pleasure and exercise enjoyment were analyzed by use of  
3 oneway, RM ANOVAs. Maximal HR was calculated using the Gellish et al. (2007) formula  
4 and percentage of maximal heart rate was calculated for the exercise bouts and associated  
5 recovery periods. Analysis of HR data was conducted by means of 3 (Condition)  $\times$  8 (Time)  
6 ANOVAs. In all ANOVAs and MANOVAs, Greenhouse–Geisser-corrected  $F$  values were  
7 used in the case of sphericity violations and pairwise comparisons were subject to Bonferroni  
8 adjustment. Music liking differences were analyzed using a paired-samples  $t$  test.

## 9 **Results**

### 10 **Data Diagnostics**

11 Data screening revealed 51 univariate outliers of which 45 were accounted for by one  
12 case that was deleted prior to the analyses. The remaining six outliers, all associated with HR  
13 measures, were adjusted until they came within the range  $z \pm 3.29$  (see Tabachnick & Fidell,  
14 2018). Normality tests indicated that HR, in particular, exhibited instances of non-normality  
15 (negative skewness) and square root transformations were applied but did not entirely remedy  
16 the non-normality; accordingly, the non-normalized data were retained for analysis. To aid  
17 interpretation of the results presented herein, descriptive statistics for all dependent measures,  
18 across conditions and throughout the HIIT protocol, are provided in Table 1.

### 19 **In-Task Psychological Variables**

20 The 3 (Condition)  $\times$  8 (Stage) MANOVA for RPE and state attention at the end of the  
21 exercise bouts indicated significant omnibus statistics, Pillai's Trace = 0.19,  $F(28, 616) =$   
22 2.26,  $p < .001$ ,  $\eta_p^2 = .93$ . Stepdown  $F$  tests indicated a significant interaction effect for RPE  
23 (see Table 2). Examination of standard errors ( $\pm 2 SE$ ) showed differences from Stage 5  
24 onwards between medium-tempo music and control (see Figure 1), with medium-tempo  
25 music yielding lower RPE. Differences also emerged between medium- and fast-tempo music  
26 at Stage 5 and Stage 8 (medium < fast). The twoway interaction for state attention was

1 nonsignificant (see Table 2 and Figure 2).

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

9 The 3 (Condition) × 8 (Stage) MANOVA for RPE and state attention at the end of the  
10 recovery period indicated significant omnibus statistics (Pillai's Trace = 0.17,  $F(28, 616) =$   
11  $2.09, p < .001; \eta_p^2 = .09$ ). Stepdown  $F$  tests indicated a significant interaction effect for RPE  
12 (see Table 2). Examination of standard errors showed differences from Stage 5 onwards  
13 between control and medium-tempo music, with the latter yielding lower RPE. There were  
14 also differences between medium- and fast-tempo music from Stages 6–8 (medium < fast; see  
15 Figure 1). The twoway interaction for state attention was nonsignificant (see Table 2 and  
16 Figure 2).

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

## 1 **In-Task Affective Measures**

2           The 3 (Condition)  $\times$  8 (Stage) MANOVA for affective measures (valence and  
3 arousal) at the end of the exercise bouts indicated significant omnibus statistics, Pillai's Trace  
4 = 0.24,  $F(28, 616) = 3.00$ ,  $p < .001$ ,  $\eta_p^2 = .12$ , and stepdown  $F$  tests indicated a significant  
5 interaction effect for arousal (see Table 2). Examination of standard errors showed  
6 differences at Stage 2 between medium-tempo music and control (medium < control), and at  
7 Stage 8 between fast-tempo music and control (fast > control; see Figure 3). The twoway  
8 interaction for affective valence was nonsignificant (see Table 2 and Figure 3).

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

20           The 3 (Condition)  $\times$  8 (Stage) MANOVA for affective measures (valence and  
21 arousal) at the end of the recovery period yielded significant omnibus statistics, Pillai's Trace  
22 = 0.14,  $F(28, 616) = 1.69$ ,  $p = .015$ ,  $\eta_p^2 = .07$ . Stepdown  $F$  tests indicated a significant  
23 twoway interaction effect for arousal (see Table 2). Examination of standard errors showed  
24 differences at Stage 1 between fast-tempo music and control (fast < control), and at Stage 6  
25 between fast-tempo music and control (fast > control; see Figure 3). The twoway interaction  
26 for affective valence was nonsignificant (see Table 2 and Figure 3).

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

### 11 **Heart Rate**

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

21           The 3 (Condition)  $\times$  8 (Stage) ANOVA for average HR during the recovery periods  
22 was significant (see Table 2), with an examination of standard errors showing that at Stages  
23 4–5, there was a difference between fast-tempo music and control (fast < control). There was  
24 no main effect of condition; however, there was a main effect of stage, with pairwise  
25 comparisons showing a gradual increase in HR through to Stage 7 (see Table 2). The 3  
26 (Condition)  $\times$  8 (Stage) ANOVA for lowest recorded HR during the recovery periods was

1 significant (see Table 2). Examination of standard errors showed differences between control  
2 and fast-tempo music at Stage 4 and Stage 5 (control > fast tempo). There was a main effect  
3 of condition; albeit pairwise comparisons showed no significant differences (see Table 2).  
4 There was also a main effect of stage, with pairwise comparisons indicating differences  
5 among all stages through to Stage 7 (i.e., lowest recorded HR increased throughout; see Table  
6 2).

### 7 **Post-Task Psychological Measures**

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

### 13 **Music Liking**

14         The *t* test for the music liking scores between the medium-tempo ( $M = 5.92$ ,  $SD =$   
15  $0.63$ ) and fast-tempo ( $M = 5.58$ ,  $SD = 0.75$ ) music conditions showed that there was no  
16 significant difference,  $t(22) = 2.05$ ,  $p = .052$ .

### 17 **Manipulation Check**

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

## 20 **Discussion**

21         The main purpose of the study was to investigate the effects of respite–active music  
22 on psychological and psychophysiological responses both during and immediately after an  
23 eight-stage HIIT protocol. In regard to  $H_1$ , it appears that medium-tempo music was generally  
24 superior during recovery periods in terms of psychological outcomes (higher affective  
25 valence/enjoyment/pleasure scores, and lower RPE), with the exception of state attention in  
26 which dissociation scores were similar across the two music conditions (see Figure 2), and so



1 it is partially accepted. With reference to  $H_2$ , which related to recovery HR, there was no  
2 clear differentiation across conditions and so it is not accepted. It is notable, however, that a  
3 main effect of condition was identified, albeit this was not associated with significant  
4 pairwise comparisons (see Table 2).  $H_3$  is accepted, as there was no Condition  $\times$  Time  
5 interaction for either average or peak HR in the exercise bouts.  $H_4$  concerned the expected  
6 lack of effect of the music manipulation on exercise bout-related measures and was only  
7 partially accepted, given that medium-tempo music elicited lower RPE scores as the HIIT  
8 stages progressed (see Table 2 and Figure 1).

### 9 **In-Task Psychological Measures**

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

19 An interesting and somewhat unexpected finding to emerge from the RPE data is that,  
20 from Stage 4, there is a marked reduction in RPE at the end of the exercise bouts with  
21 medium-tempo music, compared to the other two conditions (see Figure 1). This hints at a  
22 cumulative carryover effect of the medium-tempo music that was delivered during the  
23 recovery periods. The presence of a carryover effect counters what Crust (2004) reported  
24 when examining carryover effects of music in an isometric strength task. The strength test to  
25 failure required high effort and participants experienced localized muscle fatigue in a manner  
26 akin to HIIT protocols. Albeit Crust (2004) reported ergogenic effects of music *during* the

1 task, music exposure *prior* to the task did not have any such effects. In the present study,  
2 there seemed to be some carryover effects of respite–active music on perceptions of exertion  
3 during exercise bouts (see Figure 1).

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

#### 10 **Heart Rate (HR) Data**

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

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

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

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

### 8 **Post-Task Psychological Measures**

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

### 20 **Strengths and Limitations**

21         There have been over 300 published studies that examined pretask and in-task music  
22 applications in exercise or sport, but only a handful that have examined post-task applications  
23 (see Terry et al., 2020). This study is the first to empirically examine the relevance of music  
24 tempo during the application of respite–active music and provides insight into how the  
25 benefits of this mode of music application can be maximized. A postexperiment manipulation  
26 check indicated that 23 out of 24 participants were able to identify that there were tempo

1 differences between the two music conditions. This is a strength given that participants  
2 correctly perceived the independent variable manipulation, which allows more accurate  
3 conclusions to be drawn in regard to how the manipulation influenced the dependent  
4 variables (Thomas, Nelson, & Silverman, 2015). Moreover, as the check took place at the end  
5 of all experimental trials, it could not influence participants' responses or cognitions (e.g., via  
6 an experimenter effect) during the trials.

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

17         Respite music is an atypical music application and would require considerable  
18 planning and track editing for a playlist to contour the demands of an exercise or training  
19 session (Karageorghis, 2017). The present data indicate some utility in the adoption of  
20 playlists to match the peaks and troughs of a HIIT session with a view to positively  
21 influencing psychological responses. Note that the atypical nature of the present application  
22 of music led to the selection of a recovery period (90 s) that was longer than the typical  
23 recovery period associated with HIIT protocols (60–75 s; see e.g., Little, Safdar, Wilkin,  
24 Tarnopolsky, & Gibala, 2010). This slightly extended recovery was adopted to give the  
25 respite–active music sufficient time to take effect, but the use of brief musical excerpts (e.g.,  
26 60 s) may not be as efficacious as the 90-s excerpts used in the present study. Moreover, the

1 tempo-related recommendations presented herein should only be considered for HIIT  
2 protocols that include active recovery periods. Passive recovery is integral to many HIIT  
3 protocols and further research to examine possible differences in terms of optimal music-  
4 tempo prescription appears warranted.

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

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

1 ease with which musical works at medium tempi can be processed by the human brain.

## 2 **Implications for Practice**

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

14 On balance, medium-tempo music appears to yield the most benefits when used in  
15 between high-intensity exercise bouts and it should be noted that slow-tempo music can have  
16 a detrimental effect on subsequent anaerobic performance (see e.g., Hutchinson & O’Neil,  
17 2020). Individual exercisers might consider editing playlists, using freely available software  
18 (e.g., Audacity), for HIIT sessions that include epochs of music and silence to match their  
19 desired HIIT protocol. If the efficacy of this type of music application is established, an  
20 algorithm could be developed that creates playlists that are punctuated by periods of silence  
21 to coincide with exercise bouts.

## 22 **Conclusions and Recommendations**

23 Medium-tempo respite–active music showed the greatest capacity to influence  
24 psychological responses both during and after a HIIT session. Notably, perceptions of  
25 exertion during the exercise bouts (when no music was played) *and* recovery periods in the  
26 latter stages of a HIIT session appeared to be reduced through the use of medium-tempo

1 respite–active music when compared to a no-music control. Nonetheless, the present data  
2 clearly indicate that a decline in pleasure (i.e., exercise-related affect) is inevitable during  
3 HIIT-type protocols but music used during recovery periods can make the session seem less  
4 unpleasant. There is a need for such interventions to be studied in longitudinal studies to  
5 further understanding of how in-session manipulation of the exercise experience influences  
6 adherence in the *longue durée*. Respite–active music offers a novel music application that is  
7 inexpensive and might be considered by practitioners seeking to improve affective responses  
8 to HIIT sessions.

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28

1 Table 1  
 2 *Descriptive Statistics (M [SD]) for Dependent Measures Across Conditions for Exercise*  
 3 *Bouts (E) and Recovery Periods (R) Through Eight Stages of HIIT*

	Stage	Condition		
		Control	Medium tempo	Fast tempo
<b>RPE</b>				
	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)
<b>State Attention</b>				
	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)
<b>Feeling Scale</b>				
	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	
Felt Arousal Scale	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)	
	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)	
Heart Rate (%max)	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)	
	PACES	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)	

1

2

1 Table 2

2 *Inferential Statistics for Analyses on Psychological and Psychophysiological Measures*

	<i>F</i>	<i>df</i>	<i>p</i>	$\eta_p^2$	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)

	<i>F</i>	<i>df</i>	<i>p</i>	$\eta_p^2$	Source of Difference
<b>Felt Arousal Scale (R)</b>					
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
<b>Heart Rate Average (%max; E)</b>					
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
<b>Heart Rate Average (%max; R)</b>					
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
<b>Heart Rate Peak (%max; E)</b>					
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
<b>Heart Rate Low (%max; R)</b>					
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

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

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3



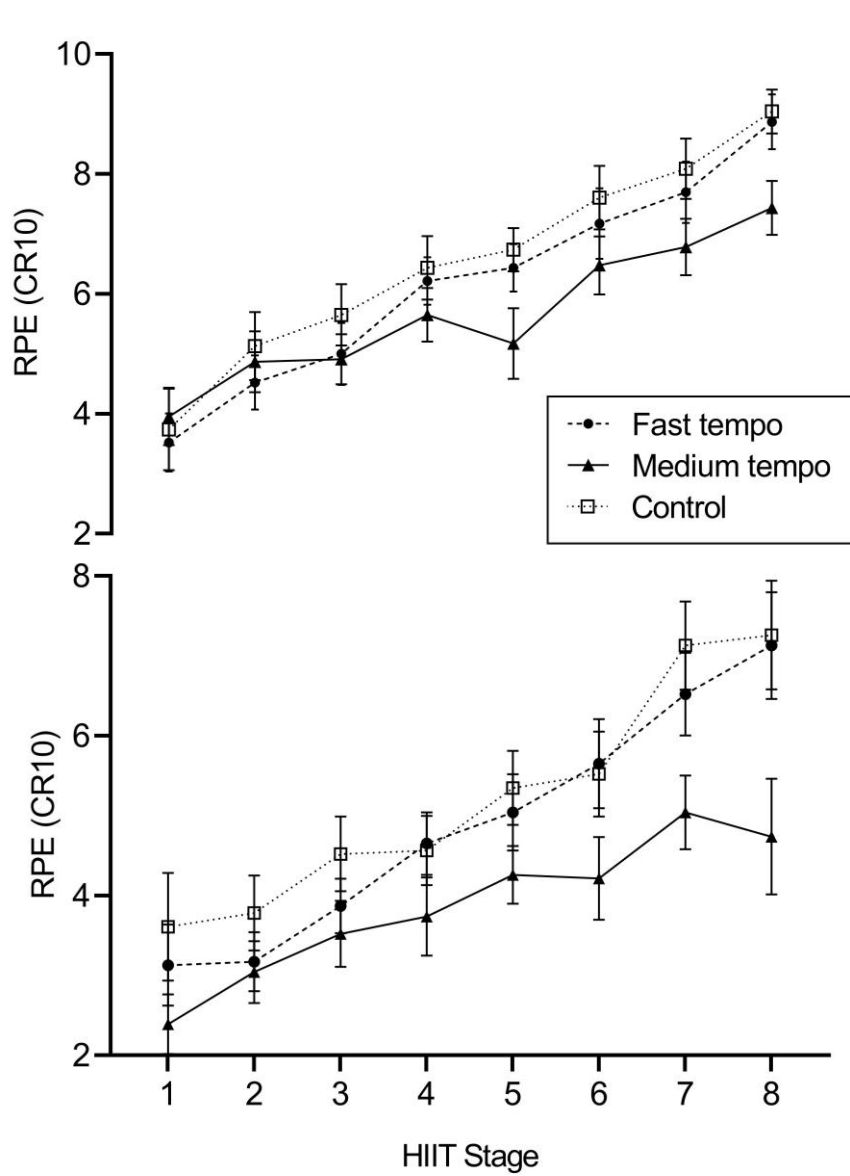


Figure 1. RPE responses across conditions during HIIT exercise bouts (top) and recovery periods (bottom). T-bars denote  $\pm 2$  standard errors.

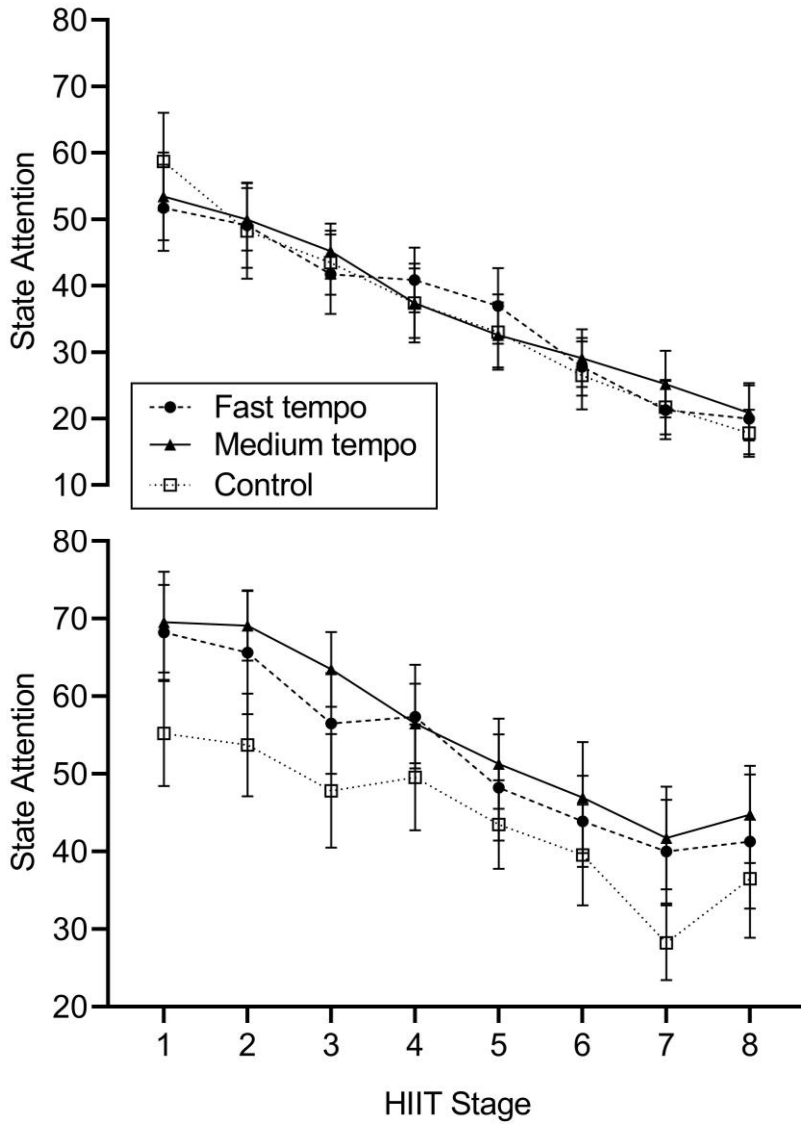
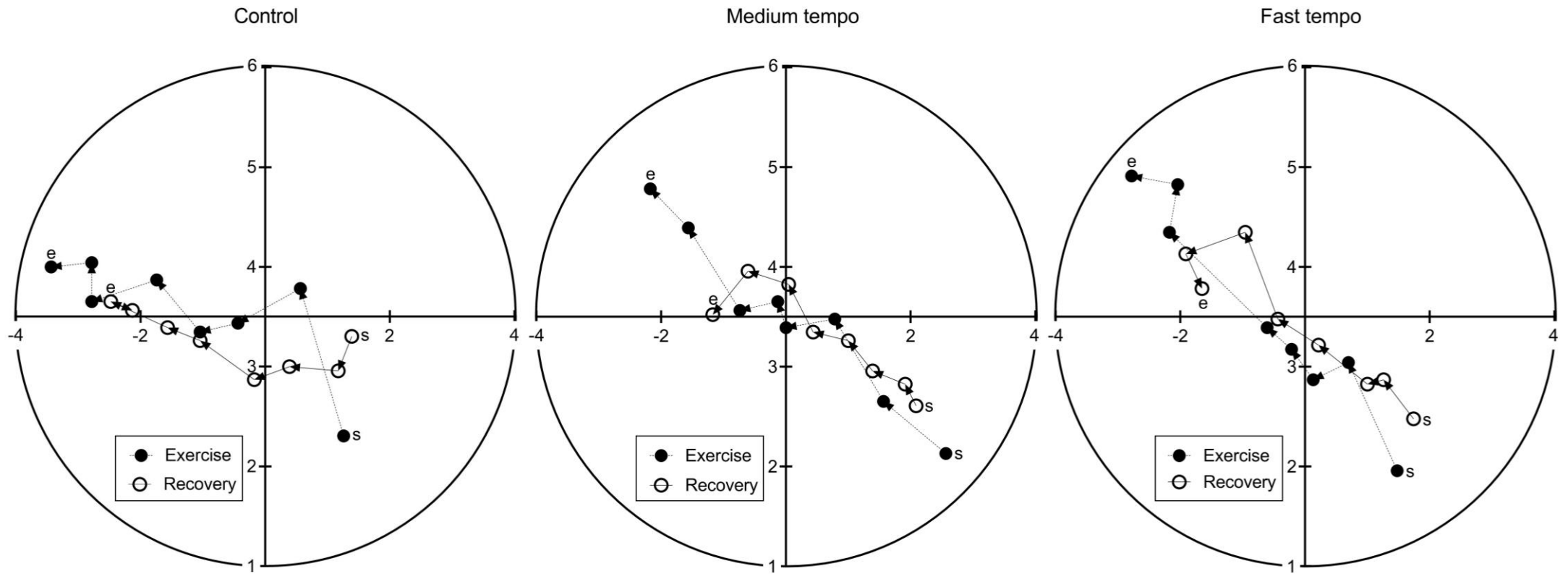


Figure 2. State attention responses across conditions during HIIT exercise bouts (top) and recovery periods (bottom). T-bars denote  $\pm 2$  standard errors.



23  
24  
25  
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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. HIIT = high-intensity interval training.