The Exercise Intensity-Music-Tempo Preference Relationship: A Decennial Revisit.

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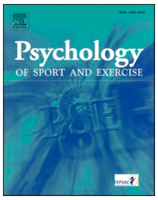

The exercise intensity–music-tempo preference relationship: A decennial revisit

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ABSTRACT

Tempo is a key determinant of the motivational effects of music during exercise and has been the focus of numerous empirical studies (e.g., Karageorghis & Jones, 2014). The present study sought to address the limitations of previous related work and revisit the relationship between exercise intensity and music-tempo preference using unfamiliar, non-lyrical music (to isolate the tempo manipulation). A within-within experimental design was employed to test hypotheses pertaining to the non-linear relationship and associated psychological outcomes (e.g., core affect and state attention). Twenty-four participants ($M_{\text{age}} = 20.6$ years, $SD = 0.92$ years) exercised at five intensities (10% of peak VO_2 below ventilatory threshold [VT]; 5% of peak VO_2 below VT, at VT, midway between VT and the respiratory compensation point [RCP], and at RCP) during which they were administered music tracks at four tempi (90 bpm, 110 bpm, 130 bpm and 150 bpm) and a no-music control. A music liking item, measures of core affect (valence and arousal), attentional focus and perceived exertion were recorded during the exercise bouts. Results indicated that unlike previous findings with familiar, lyrical music, there was no discernible relationship between exercise intensity and preference for music tempo. The most positive psychological outcomes were associated with fast-tempo music. In accord with previous findings, slow-tempo music attracted low liking scores and the least desirable psychological outcomes at every exercise intensity. The present findings have implications for the use of unfamiliar, non-lyrical music during exercise. Specifically, that such music should be ~10 bpm faster than familiar, lyrical music.

1. Introduction

There is a rapidly growing literature on the psychological, psychophysical and ergogenic effects of music in the exercise domain (see Delleli et al., 2023; Terry et al., 2020 for meta-analyses). A major focus for researchers has been to identify the musical qualities that elicit potentially beneficial psychological and psychophysical effects. Experimenters have typically manipulated musical qualities such as sound intensity (volume), style/idiom, rhythm and lyrical content (e.g., Karageorghis et al., 2018; Sanchez et al., 2016). From both research and applied perspectives, one of the qualities of music that is most amenable to manipulation is its speed or tempo, as measured in beats per minute (bpm). Tempo has received extensive coverage in the literature and is considered to be a key determinant of musical response (e.g., Feiss et al., 2021; Karageorghis, 2020).

A biomusicological phenomenon that has been used to explain the effects of the rhythmic qualities of music on the mind–body relationship is that of entrainment (see Karageorghis, 2017). Specifically, music can influence the main pulses of the body, such as brainwaves, heart rate and respiratory rate (e.g., Bigliassi et al., 2018; Karageorghis et al., 2018). For example, using electroencephalography combined with electromyography, Bigliassi et al. (2017) showed how the asynchronous application of music (i.e., without participants consciously synchronising their movement rate with the rhythmical qualities of the music) during a submaximal cycle ergometer task led to inhibition of alpha resynchronization at the Cz electrode site, coupled with higher root mean square amplitudes in the vastus lateralis.

1.1. *The exercise heart rate–music-tempo preference relationship*

Theorists have posited that music-tempo preference is determined by the listener's level of activation and the context in which the music is heard (Berlyne, 1973; Karageorghis, 2017). Accordingly, when a listener is highly activated (e.g., during high-intensity exercise) the implication is that faster tempi (i.e., >130 bpm) will be preferred. Allied to this, there are tasks or situations that demand high levels of psychomotor arousal (e.g., sprint

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intervals on a cycle ergometer), and fast, stimulative music can be conducive to superior performance (e.g., Stork et al., 2019). Predicated on the results of two exploratory studies (Karageorghis et al., 2006, 2008), Karageorghis and Terry (2009) advanced the case for the relationship between exercise/physical training intensity and music preference not being linear in nature, as had been previously suggested (e.g., Iwanaga, 1995).

In a subsequent study that employed a cycle ergometer task, a non-linear relationship was demonstrated, and this exhibited a cubic trajectory (i.e., two points of inflection; Karageorghis et al., 2011). The experimenters administered musical excerpts in four categories of tempo (slow – 95–100 bpm, medium – 115–120 bpm, fast – 135–140 bpm and very fast – 155–160 bpm), across six exercise intensities (40–90% heart rate reserve [maxHRR]). Similarly, a non-linear (quadratic; one point of inflection) relationship between preference for music tempo and exercise heart rate was reported by Karageorghis and Jones (2014), who administered a treadmill exercise task. Across both studies directly examining the nature of the relationship, the range of preferred tempi across exercise modalities was relatively narrow (120–140 bpm) when applying music in the asynchronous mode. While there were differences in the precise nature of the relationship between cycle ergometer and treadmill exercise, research has shown that preference for music tempo does not follow a linear relationship with exercise heart rate (see Karageorghis, 2016 for a review).

A limitation that characterises the four studies that precede the present is that exercise intensity was set with reference to heart rate, as opposed to biological markers such as ventilatory threshold (VT). This can result in between-subject variation in exercise intensity (Karageorghis et al., 2021) and lead to challenges when interpreting data with reference to exercise intensity domain (e.g., ACSM, 2020; moderate, heavy, severe) and affective responses (Ekkakakis et al, 2020). The present study is grounded in the Dual-Mode Theory of affective responses to exercise (Ekkekakis, 2003; Ekkekakis et al., 2020), which views VT and RCP as key turn-points in terms of exercise-related affect (see Ekkekakis, 2009). Hence, the five exercise intensities that are tested in this study use VT and respiratory compensation point (RCP) as biological markers of exercise intensity. The nature of affective responses to music has not been addressed extensively in relation to these important biological markers (see Karageorghis, 2020).

1.2. *Psychological effects of music tempo during exercise*

Preference for music tempo is considered a higher-order construct (see Stanovich, 2008), relates to choices among alternatives and entails an evaluative judgement (Scherer, 2005). When considering a broader role of music use in exercise, there are other constructs that have been shown to be relevant (see Terry et al., 2020). If a purpose of music use during exercise is to promote a more pleasant experience (e.g., Jones & Zenko, 2021), it is important to consider the role of tempo in modulating exercise-related affect. Core affect is conceptualised with reference to two dimensions; namely valence (pleasure–displeasure) and arousal/activation (activation–deactivation), in accord with the Circumplex Model of Affect (see Posner et al., 2005). Greater understanding of which music tempi can promote pleasant exercise experiences across a range of intensities would be of use to exercise practitioners and participants in their creation of playlists.

The effectiveness of music in influencing core affect is thought to be underpinned by the notion of *dissociation* (Karageorghis et al., 2018b), which has been conceptualised as the focus of attention away from bodily sensations (see Tammen, 1996). It is closely linked to perceived exertion, a psychophysical construct that has been examined in numerous experimental studies (e.g., Feiss et al., 2021; Terry et al., 2012). Music has been shown to lower the rating of perceived exertion (RPE; Borg, 1982) when workloads are standardised across participants (see Terry et al., 2020). However, the effects of music appear reduced during high-intensity tasks in non-highly trained samples (e.g., Stork et al., 2019).

A decade ago, Karageorghis and Jones (2014) examined core affect and attentional focus in response to a no-music control condition and four music-tempo conditions (slow – 95 bpm, medium – 115 bpm, fast – 135 bpm and very fast – 155 bpm) across a wide range of exercise intensities, determined by percentage of maximal heart rate. In-task measures of affective valence indicated that all music conditions led to greater pleasure vs. no-music control, and that medium-tempo music elicited the greatest pleasure. Attentional focus data indicated greater associative focus during no-music compared to all music tempi. Extant findings show that optimal music selection should be associated with more positive affective valence, elevated affective arousal, lower perceived exertion and more dissociative attentional focus (Hutchinson et al., 2018; Karageorghis et al., 2021; Terry et al., 2020). Such work, however, has been limited by the exclusive use of familiar, lyrical music, with which it is challenging to isolate the effects of tempo (Karageorghis & Jones, 2014).

There is a need to mitigate familiarity-related biases and the effects of syntactic processing associated with lyrical content (Sanchez et al., 2016). There is also value in the inclusion of a range of psychological and psychophysical outcome variables (e.g., core affect, state attention and rating of perceived exertion) to gauge the practical utility of the exercise intensity–music-tempo preference relationship. Such a study would serve to extend the scope of the preceding set of four studies (Karageorghis et al., 2006, 2008, 2011; Karageorghis & Jones, 2014), embrace the best elements of those studies (e.g., a wide range of music tempi and exercise intensities), and address their methodological shortcomings. Moreover, exercise practitioners would be able to apply the emergent findings and gauge the impact of tempo manipulations on a range of outcomes.

1.3. *Previous analytical approaches*

As preference entails a choice among several alternatives, a possible research approach would entail playing consecutive music tracks during a mono-intensity exercise bout while soliciting preference ratings. This presents feasibility issues and raises additional concerns pertaining to fatigue, carryover and order effects. In attempts to avoid such methodological issues, previous analytical approaches have entailed use of a mean of music liking scores of the most preferred tempo at each exercise intensity (e.g., Karageorghis & Jones, 2014). While such approaches certainly hold utility for practitioners, they are confounded by the fact that exacting preferences of music tempo at any given exercise intensity are lost. To circumvent this methodological concern, music liking data can be configured to depict preference rankings at each exercise intensity – an approach adopted in the present study.

1.4. *Purpose and hypotheses*

The purpose of the next study in this line of work was to assess the expected non-linear exercise heart rate–music tempo relationship while standardising physiological load with reference to ventilatory threshold (cf. Dual-Mode Theory; Ekkekakis, 2003) and by use of unfamiliar, non-lyrical music. It was hypothesised that a cubic relationship would emerge in the exercise intensity–music-tempo preference relationship (H_1) owing to the previously recorded relationship observed during cycle ergometry (Karageorghis et al., 2011). A secondary hypothesis was that the most positive psychological and psychophysical outcomes would be associated with the fast-tempo music condition, given that this was the only condition that fell within the optimal tempo range (120–140 bpm) identified across a range of exercise intensities in previous research (e.g., Karageorghis et al., 2011; H_2).

2. Method

2.1. *Participants*

A power analysis was conducted using G*Power 3.1 (Faul et al., 2007), which indicated that 20 participants would be required based on a medium-to-large effect size ($\eta_p^2 = 0.12$; Karageorghis & Jones, 2014), and power at 0.95 in a repeated-measures design. An additional four participants were recruited to account for removal due to outliers and participant dropout. Twenty-four participants ($M_{\text{age}} = 20.6$ years, $SD = 0.92$ years; $M_{\text{BMI}} = 23.3$, $SD = 4.4$; 11 female), completed all sessions. They were recreationally active and did not report any health concerns (i.e., they were deemed to be fit and healthy).

2.2. *Apparatus and measures*

An electronically braked cycle ergometer (Lode Corival) was used for all sessions and music was delivered via an mp3 player (iPod Classic) connected to speakers (Genelec 8040 B). Sound intensity was standardised at 75 dBA and monitored using a sound meter app (Splend Apps). Affective valence (i.e., pleasure–displeasure) was assessed using the Feeling Scale (FS: Hardy & Rejeski, 1989) and affective arousal (i.e., activation–deactivation) using the Felt Arousal Scale (FAS; Svebak & Murgatroyd, 1985). Music liking was assessed by means of a 10-point scale (see Karageorghis & Jones, 2014). State attention was recorded using a numeric response scale based on Tammen's (1996) Attention Scale. Rating of perceived exertion (RPE) was assessed using Borg's (1982) CR-10 Scale.

2.3. *Music selection*

The music tracks deemed to be suitable experimental selections for the study were required to be of at least 90-s duration with no lyrical content. The exclusion of lyrical content addressed one of the potential threats to internal validity when singling out the musical quality of tempo (Sanchez et al., 2016). Online music streaming services were searched for potentially appropriate tracks at each tempo, before consensus was sought among the research team to confirm that the four tracks selected were of a similar genre (electronic dance music; EDM), complexity, mode and rhythmic structure. Three of the music tracks (90 bpm[1], 110 bpm[2], and 130 bpm[3]) were sourced from Spotify and one from Adobe Stock Audio (150 bpm[4]). To reduce the likelihood of participants being familiar with the selections, tracks identified via Spotify were required to have <50,000 streams. Music was applied in the asynchronous mode, with care taken to ensure that auditory-motor synchronisation was not possible in any exercise intensity–music-tempo combination.

2.4. *Pre-test and habituation*

Participants completed a ramp protocol on a cycle ergometer designed to elicit maximal aerobic capacity. Three protocols were developed and administered depending on the physical stature of the participant; all protocols began at 35 W and increased, by 15 W, 20 W or 25 W per min. The protocol was terminated at the point of volitional exhaustion. Peak oxygen uptake, VT and RCP were identified offline using software (Winbreak), based on the three-method procedure of Gaskill et al. (2001). A habituation session followed the maximal test with the outcome measures (i.e., FS, FAS, state attention and RPE) explained to each participant. Participants then completed two bouts of 90-s exercise at a low intensity (50 W), while listening to a non-experimental music excerpt and responding to the aforementioned items.

2.5. *Experimental trials*

There were four experimental conditions: Slow-tempo music (90 bpm), medium-tempo music (110 bpm), fast-tempo music (130 bpm) and very fast-tempo music (150 bpm). There was also a no-music control condition. Participants completed test sessions individually and were administered four music excerpts and a no-music control while exercising at five intensities: 10% of peak capacity below VT, 5% of peak capacity below VT, at VT, halfway between VT and RCP (Δ50% VT–RCP), and at RCP. Accordingly, each participant completed a total of 25 conditions and visited the laboratory on four occasions (maximal test and habituation during Visit 1, and three subsequent visits to complete the experimental trials).

Each experimental test session included a 5-min warm-up starting at 20% below VT and increasing to a wattage equivalent to VT. For Visit 2 and Visit 3, immediately following the warm-up, the participant began the experimental trials of 90 s at a wattage corresponding to one of the predetermined exercise intensities at 80 rpm, and listening to one of the music excerpts (or the no-music control). Following the 90-s bout, the participant engaged in active recovery for 60 s with the resistance reducing to 30 W and self-selected rpm. A mental arithmetic task (e.g., nine-times table backwards starting from 108) was used during the 60-s recovery periods to reduce the likelihood of music carryover from one trial to the next (see Karageorghis et al., 2008). This pattern was repeated until five trials (each with a different music excerpt) were completed at one exercise intensity.

Following the five exercise bouts, the participant was afforded a 10-min rest off the cycle ergometer. Subsequently, they completed a 5-min warm-up as previously described and then began working at one of the predetermined exercise intensities to complete five exercise bouts of 90- s. During the bouts, participants were administered a music excerpt or the control condition, separated by 60-s active recovery with resistance reduced to 30 W and at a self-selected rpm. For Visit 4, participants completed the same pattern of warm-up, 90-s bouts and 60-s active recovery while exercising at their remaining intensity. The order of exercise intensities and music conditions was randomised, as full counterbalancing was not possible (Harris et al., 2021). The order of exercise intensities was randomised first, followed by the order of conditions at each exercise intensity. Randomisation was conducted in Microsoft Excel (2021). Participants were unable to view heart rate data and cycle ergometer feedback, such as wattage and rpm, during testing. If the rpm fell outside the range 75–85 rpm, the participant was instructed to pedal either faster or slower, as appropriate.

Baseline measures of FS and FAS were recorded at the start of each visit to the laboratory. Fifteen seconds before the end of each experimental condition, the FS, FAS, music liking, CR-10 and state attention scale were administered. The order of measures was changed for each participant at each administration to minimise the possibility of response order effects (Ejelöv & Luke, 2020).

2.6. *Data analysis*

Screening and diagnostics tests were used to ensure that the data were suitable for parametric analysis. A series of two-factor, repeated-measures (RM) 5 (Condition) × 5 (Exercise Intensity) ANOVAs was computed for the FS, FAS, state attention and RPE data. Music liking scores were analysed by means of a two-factor 4 (Condition) × 5 (Exercise Intensity) RM ANOVA. These scores were also analysed using within-subjects polynomial contrasts to explore the trajectory of the exercise intensity–music-tempo preference relationship. Pre-test, baseline FS and FAS scores were analysed by means of separate RM ANOVAs. Alpha was set at 0.05 and effect sizes (η_p^2) are reported.

3. Results

Data screening for univariate outliers indicated no outliers. Two deviations from normality ($p < 0.001$; RPE scores during slow-tempo music at VT, and FS scores during very fast-tempo music at the between VT and RCP intensity) were identified, but as these are self-report data, they were not

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[1] https://open.spotify.com/track/0pvYzUbxPHqnXKHegK5dPp?si=e0043e34581d4472

[2] https://open.spotify.com/track/1Y6DPnG7RT8sUmIi71mXEC?si=c207e91a9773411c

[3] https://open.spotify.com/track/4kuHwQJWCpSgHKBtTQcnc1?si=df56c2af0f194ea3

[4] https://stock.adobe.com/uk/search/audio?k=515295255

transformed (see Nevill & Lane, 2007). Greenhouse–Geisser-adjusted *F* values are reported where the assumption of sphericity was violated.

3.1. *Pre-task assessment of differences in core affect*

RM ANOVA of baseline FS scores collected prior to commencement of exercise for each laboratory visit indicated no differences, $F(4, 92) = 1.04$, $p = 0.392$, $\eta_p^2 = 0.04$. Similarly, baseline FAS scores did not differ, $F(4, 92) = 0.91$, $p = 0.462$, $\eta_p^2 = 0.04$.

3.2. *In-task responses*

3.2.1. *Music liking*

A two-way 4 (Condition) × 5 (Exercise Intensity) RM ANOVA

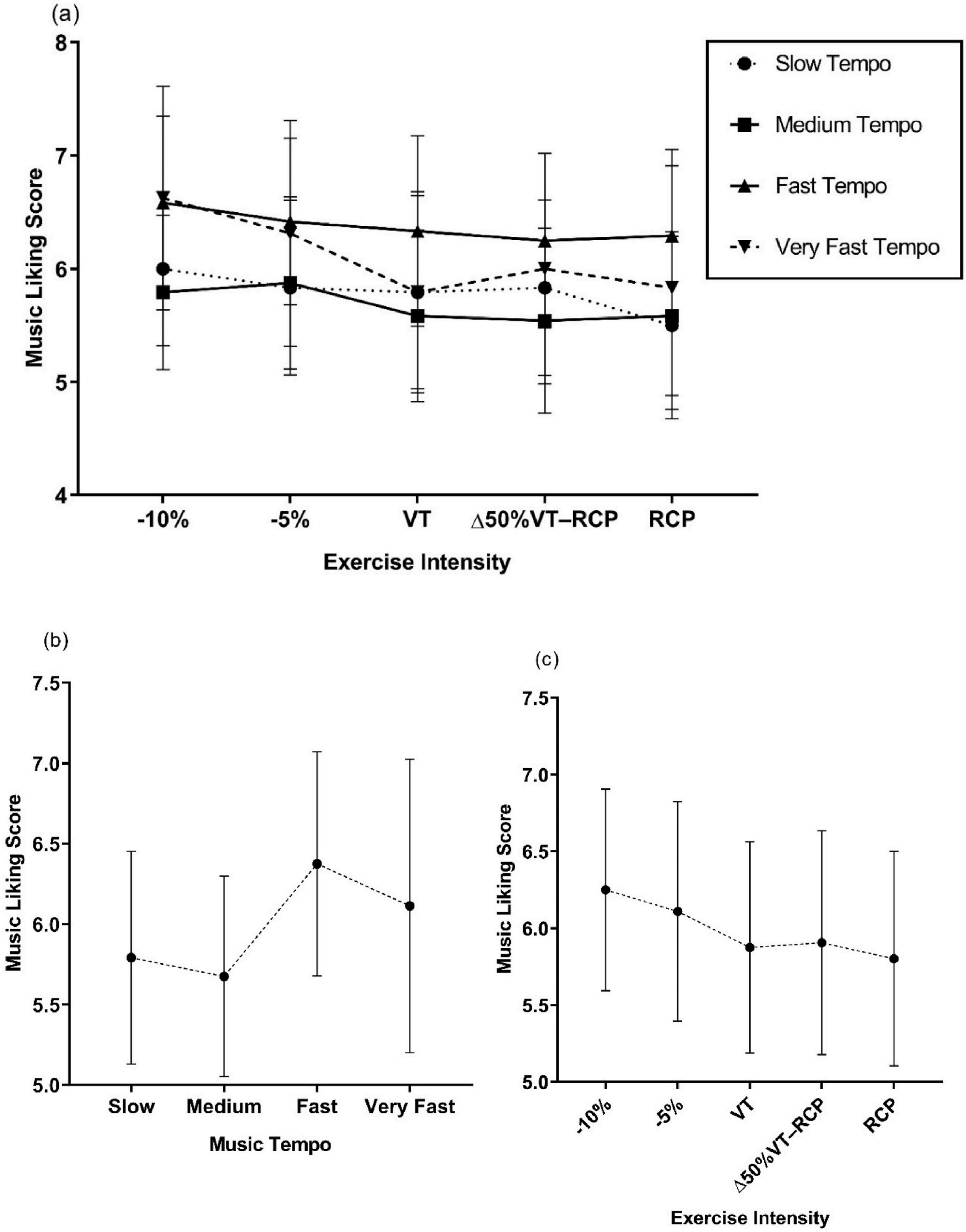

Figure 1. (a) The non-significant ($p > 0.05$) two-way Music Condition × Exercise Intensity interaction for music liking, (b) The significant ($p = 0.016$) cubic relationship for music tempo; and (c) The significant ($p = 0.006$) linear relationship for exercise intensity.
Note. Error bars denote 95% CIs.

showed no interaction effects, $F(5.95, 136.73) = 0.559$, $p = 0.761$, $\eta_p^2 = 0.02$, or main effects of condition, $F(1.87, 42.91) = 2.819$, $p = 0.074$, $\eta_p^2 = 0.11$, or intensity, $F(4, 92) = 1.808$, $p = 0.134$, $\eta_p^2 = 0.07$.

Polynomial contrasts. There were no significant within-subjects polynomial contrasts for the exercise intensity–music tempo preference relationship ($ps > 0.05$; see Figure 1a). A cubic relationship emerged for condition ($p = 0.016$, $\eta_p^2 = 0.23$) with the two inflection points representing changes in preference between medium and fast-tempo music, and between fast and very fast-tempo music (see Figure 1b). There was, however, no main effect of condition (music-tempo manipulation). A linear relationship emerged for exercise intensity ($p = 0.006$, $\eta_p^2 = 0.29$), characterised by declining music liking scores as exercise intensity increased (see Figure 1c).

To aid practical interpretation of the music liking data, the 1–10 scores were converted to a ranking for each music tempo at each intensity, and Figure 2 shows the number of times a music track was ranked first at each intensity. Fast tempo and/or very fast-tempo music were ranked first most frequently at each of the five exercise intensities.

3.3. Affective responses

3.3.1. Affective valence

A two-way 5 (Condition) × 5 (Exercise Intensity) RM ANOVA indicated no significant interaction effects for affective valence (FS scores), $F(7.91, 181.98)$, $p = 0.442$, $\eta_p^2 = 0.04$. There was, however, a main effect of condition, $F(2.60, 59.80) = 5.54$, $p = 0.003$, $\eta_p^2 = 0.19$, with follow-up pairwise comparisons indicating that fast-tempo music elicited higher FS scores than the no-music control ($p = 0.037$; Figure 3). There was also a significant main effect of intensity, $F(2.54, 58.48) = 16.44$, $p < 0.001$, $\eta_p^2 = 0.42$, with pairwise comparisons indicating that FS scores at RCP were significantly lower than at all other intensities ($p < 0.001$).

3.3.2. Affective arousal

A two-way 5 (Condition) × 5 (Exercise Intensity) RM ANOVA indicated no significant interaction effects for affective arousal, $F(8.83, 203.17) = 1.24$, $p = 0.276$, $\eta_p^2 = 0.05$, or a main effect of intensity, $F(2.88, 66.32) = 1.508$, $p = 0.222$, $\eta_p^2 = 0.06$. There was, however, a main effect of condition, $F(1.78, 40.93) = 8.62$, $p = 0.001$, $\eta_p^2 = 0.27$, with pairwise comparisons indicating higher FAS scores for fast-tempo ($p = 0.024$) and very fast-tempo music ($p = 0.018$), compared to control.

3.4. State attention

A two-way 5 (Condition) × 5 (Exercise Intensity) RM ANOVA on state attention scores showed no significant interaction effects, $F(8.35, 192.02) = 0.717$, $p = 0.682$, $\eta_p^2 = 0.03$. There was, however, a significant main effect of condition, $F(1.39, 31.99) = 8.10$, $p = 0.004$, $\eta_p^2 = 0.26$, with pairwise comparisons indicating significantly greater dissociation during the fast-tempo condition compared to control ($p = 0.029$; see Figure 4). There was also a significant main effect of intensity, $F(2.72, 62.53) = 18.16$, $p < 0.001$, $\eta_p^2 = 0.44$, with pairwise comparisons indicating more associative attention at RCP when compared to all other intensities ($p < 0.001$).

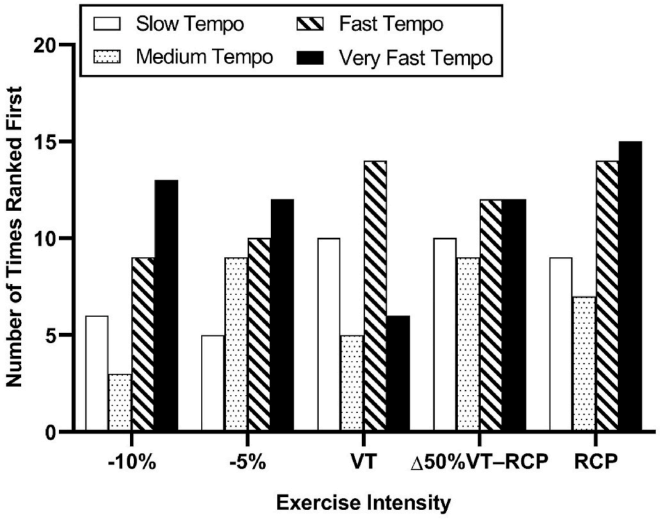

Figure 2. Preference rankings for music tempi across exercise intensites.

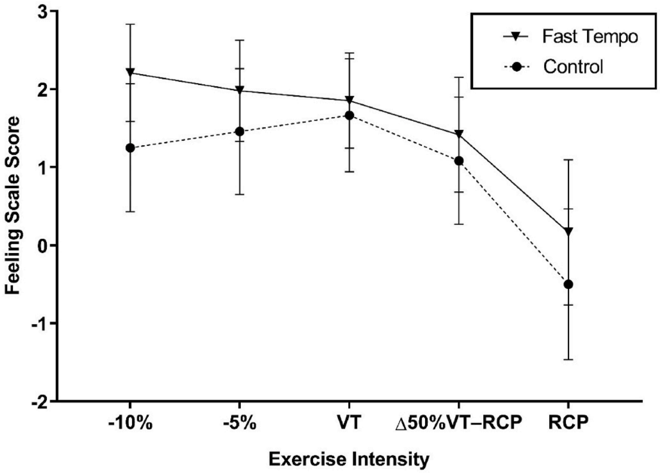

Figure 3. Mean Feeling Scale scores for fast-tempo music and no-music control conditions at each exercise intensity ($p = 0.037$).
Note. The error bars denote 95% CIs.

3.5. Rating of perceived exertion (RPE)

A two-way 5 (Condition) × 5 (Exercise Intensity) RM ANOVA indicated a significant interaction effect, $F(6.59, 150.59) = 2.76$, $p = 0.012$, $\eta_p^2 = 0.11$. Inspection of plotted data (see Figure 5) indicated that when compared to other conditions, a higher RPE score for fast-tempo music at the −10%VT exercise intensity, coupled with a lower RPE score for the same condition at the Δ50%VT–RCP intensity, drove the significant interaction. There was no main effect of condition, $F(4, 92) = 0.57$, $p = 0.69$, $\eta_p^2 = 0.02$. There was, however, a main effect of intensity, $F(4, 92) = 21.27$, $p < 0.001$, $\eta_p^2 = 0.48$. Follow-up pairwise comparisons indicated significantly ($p = 0.023$) higher RPE scores at the Δ50%VT–RCP condition compared to −10%VT. Also, significantly ($p = 0.049$) higher

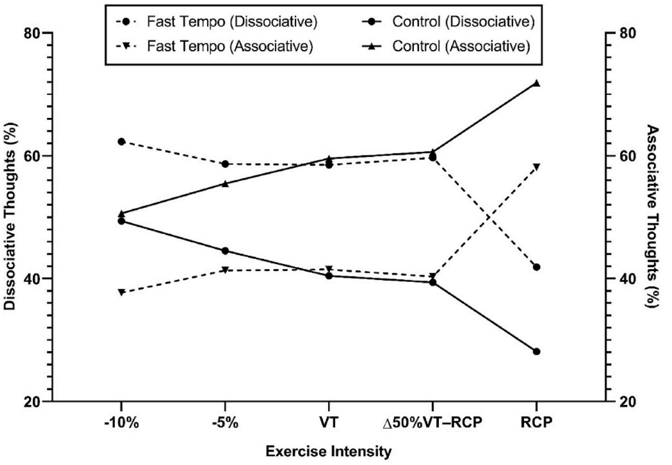

Figure 4. Mean state attention scores for fast-tempo music and no-music control conditions at each exercise intensity ($p = 0.029$).

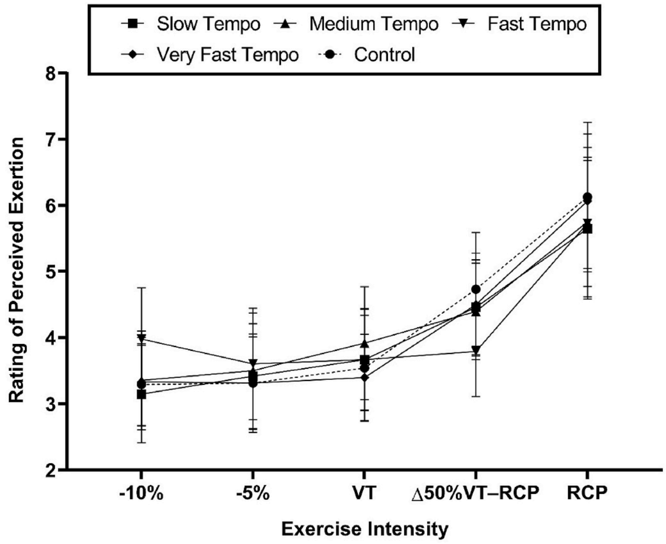

Figure 5. The two-way Music Condition × Exercise Intensity interaction for RPE ($p = 0.012$).
Note. Error bars denote 95% CIs.

RPE scores during the Δ50%VT–RCP condition, and −5%VT, and significantly (*ps* < 0.01) higher RPE scores in the RCP condition compared to all other intensities.

4. Discussion

The main purpose of this study was to examine the exercise intensity–music-tempo preference relationship using unfamiliar, non-lyrical music. The hypothesis that a cubic relationship would emerge (H_1) is not supported. The hypothesis that the most positive psychological and psychophysical outcomes would be associated with the fast-tempo condition (H_2) is only partially supported, given that RPE scores were not lowest under the fast-tempo condition (see Table 1 and Figure 5).

4.1. *Music liking across exercise intensities*

The present findings suggest that with unfamiliar, non-lyrical music, there is no discernible relationship between exercise intensity and preference for music tempo (see Figure 1a and Figure 2). This finding stands in contrast to those of closely related studies that used lyrical, familiar music and a cycle ergometer task (e.g., Karageorghis et al., 2011). One aspect of the present findings that serves to echo previous findings (e.g., Karageorghis et al., 2006, 2011) is that slow tempo-music is inappropriate for all exercise intensities during a continuous, rhythmic activity such as cycle ergometry. Where there is some discrepancy with all previous related findings (e.g., Karageorghis et al., 2011; Karageorghis & Jones, 2014), is the degree of preference for very fast-tempo music at the lower exercise intensities (see Figure 2). Taking a macroscopic approach, it seems that with unfamiliar, non-lyrical music, there is an upward shift of ~10 bpm in the preference for music tempo, when compared to lyrical, familiar music.

We can speculate as to the reasons for this shift, and among plausible explanations lies the stimulation and syntactic processing associated with lyrical content in music (Sanchez et al., 2016). Accordingly, the absence of lyrics might avail greater attentional processing capacity when using music during exercise, leading to a preference for higher tempi. An alternative explanation concerns the lack of familiarity, which causes less engagement and personal investment in the music (cf. Hallett & Lamont, 2015). This coupled with the relative simplicity of the tracks selected, might account for the greater preference for higher tempi when the present findings are considered in light of extant findings (e.g., Karageorghis et al., 2011; Karageorghis & Jones, 2014).

It is notable that across the range of exercise intensities, there was greater preference for fast- or very fast-tempo music (see Figure 2). The fast-tempo music was also associated with the most positive psychological outcomes (core affect and state attention), but not so for the psychophysical outcome (RPE). The finding concerning psychological outcomes contrasts with the finding of Karageorghis and Jones (2014), who reported that the most positive psychological outcomes were associated with medium-tempo music. There is no discernible pattern in how exercise intensity and music-tempo preference relate to RPE (see Figure 5). As

Table 1
Descriptive statistics for each dependent variable across five exercise intensities.

		Feeling Scale		Felt Arousal Scale		State Attention		RPE	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
10% < VT	NM	1.25	1.94	2.96	1.04	49.38	22.62	3.29	1.46
	ST	2.29	1.63	3.65	0.87	56.46	19.53	3.15	1.74
	M	1.88	1.48	3.63	0.97	57.04	18.11	3.35	1.77
	FT	2.21	1.47	4.04	1.04	62.29	20.75	3.98	1.83
	VF	2.17	1.49	3.83	0.92	60.58	21.54	3.33	1.58
5% < VT	NM	1.46	1.91	3.31	1.18	44.54	24.92	3.31	1.76
	ST	1.88	1.65	3.73	0.86	58.25	16.54	3.42	1.89
	MT	2.00	1.77	3.77	0.79	57.21	16.49	3.50	2.07
	FT	1.98	1.54	3.92	0.84	58.67	18.94	3.60	1.99
	VF	2.13	1.48	4.04	0.76	58.42	18.44	3.31	1.65
VT	NM	1.67	1.71	3.31	1.20	40.46	24.70	3.54	1.88
	ST	2.00	1.35	3.71	0.95	54.79	18.09	3.67	1.83
	MT	1.71	1.52	3.75	1.03	52.75	16.34	3.92	2.01
	FT	1.85	1.44	3.83	1.09	58.50	15.23	3.67	1.81
	VF	1.75	1.73	3.88	0.95	54.13	18.38	3.40	1.55
Δ50%VT–RCP	NM	1.08	1.93	3.67	1.27	39.38	23.42	4.73	2.04
	ST	1.50	1.77	4.02	0.87	47.75	14.01	4.46	1.69
	MT	1.42	2.00	4.04	0.75	52.42	16.93	4.40	1.73
	FT	1.42	1.74	3.96	0.81	59.67	11.23	3.79	1.61
	VF	1.54	1.69	4.13	0.85	54.33	18.39	4.50	1.84
RCP	NM	−0.50	2.28	3.52	1.41	28.13	18.23	6.13	2.68
	ST	0.29	2.20	4.00	1.14	36.25	19.07	5.65	2.44
	MT	0.08	2.10	3.83	1.17	36.13	17.10	5.75	2.31
	FT	0.17	2.20	3.83	1.17	41.88	23.21	5.73	2.71
	VF	−0.04	2.39	4.10	1.12	39.79	21.74	6.06	2.42

Note. RPE = rating of perceived exertion, VT = ventilatory threshold, Δ50%VT–RCP = midway between VT and RCP, RCP = respiratory compensation point, NM = no music (control), ST = slow-tempo condition, MT = medium-tempo condition, FT = fast-tempo condition, VF = very fast-tempo condition expected, however, RPE scores increased sharply between Δ50%VT and RCP, and the presence of music – regardless of tempo – could not mitigate this increase (cf. Ekkekakis, 2003; Ekkekakis et al., 2020).

4.2. Strengths and weaknesses

A distinct strength of the present study when set in apposition to its predecessors was the standardisation of physiological load with reference to ventilatory threshold, and not age-predicted maximal HR (e.g., Karageorghis et al., 2008). This approach ensured that participants were working at comparable intensities at each level of the exercise intensity independent variable. Along similar lines, the use of unfamiliar, non-lyrical music affords an opportunity to better single out participants' responses to the tempo dimension of music, when compared to the familiar/lyrical tracks of preceding studies (e.g., Karageorghis et al., 2006; Karageorghis & Jones, 2014). A further strength entailed a comprehensive music-selection procedure in which the research team endeavoured to standardise the four experimental music selections in terms of familiarity (low), genre, complexity, mode and rhythmic structure (cf. Karageorghis, 2016).

The present study was not without some limitations and perhaps chief among these was the degree to which the musical stimuli were representative of what exercisers typically use in the field (i.e., ecological validity). Albeit that instrumental/non-lyrical tracks are frequently used and non-familiar tracks are sometimes used (e.g., through radio airplay or algorithm suggestions), the combination of non-lyrical with unfamiliar is rare, as exercisers have a tendency to self-select tracks from a preferred pool of musical selections (see e.g., Hallett & Lamont, 2015). Nonetheless, the reduction in ecological validity was necessary to single out the musical quality of tempo.

A further limitation was the degree to which establishment of exercise intensity with reference to biological markers limits the degree of comparability with previous studies that had used age-predicted maximal heart rate (e.g., Karageorghis et al., 2008; Karageorghis et al., 2011). Along similar lines, there are small variations in the tempo selections tested across studies. For example, Karageorghis et al. (2011) used 135–140 bpm for "fast-tempo music", while 130 bpm was under this rubric in the present study. There is, however, good reason for such variations because different music epochs have different tempi bands from which popular tracks emerge. By way of illustration, in a hip-hop dominated epoch, tempi are relatively slow (i.e., ~70–100 bpm), and in a rock 'n' roll dominated epoch, tempi are relatively fast (i.e., ~130–170 bpm; see Karageorghis, 2017).

4.3. Implications for practice and future research

The present findings hold several implications for applied practice. Although with familiar/lyrical music, the relationship between exercise intensity and preferred tempo has previously been characterised as cubic in nature (e.g., Karageorghis et al., 2011), with the use of unfamiliar/non-lyrical music there is no discernible relationship (see Figure 1a). What is common across studies in this lineage, however, is that slow-tempo music is inappropriate for the full gamut of exercise intensities; unless used for cool-down/recuperation (see e.g., Jing & Xudong, 2008; Karageorghis et al., 2018). Slow music should, therefore, generally be avoided during repetitive, aerobic-based exercise. Where slow music is used to teach motor skills to beginner exercisers, it might be appropriate, or when used in the synchronous mode for slow movement patterns (see Karageorghis, 2017).

The present music choices were 'homogenised', as far as possible, in order to single out the tempo manipulation. It is highly unlikely that the music tracks would have been known to participants and due to this aspect, the aesthetic appreciation, as represented through the music liking score, was lower for all tracks in the present study when compared to its predecessors (e.g., Karageorghis et al., 2006, 2011). This finding suggests that the use of familiar tracks is important from the standpoint of heightening exercisers' aesthetic response to music (cf. Berlyne, 1973). In previous related studies that used familiar music (e.g., Karageorghis et al., 2011; Karageorghis & Jones, 2014), it proved challenging to disentangle familiarity from the exercise intensity–music tempo relationship. The notion of extra-musical association has also been shown to be seminal in shaping affective responses to music (see e.g., Bishop et al., 2007). The lyrical component of music can offer a welcome distraction, leading to higher levels of dissociation during exercise (Karageorghis & Priest, 2008; Sanchez et al., 2016). Moreover, lyrics can provide affirmations (e.g., "you're simply the best"), a 'hook' into the music ("I like to move it, move it") or a verbal prompt to keep going (e.g., "keep on running").

An interesting implication of the present findings for applied practice concerns the seemingly inappropriate nature of medium-tempo music across all of the exercise intensities tested (see Figure 1a and Figure 2). Whereas familiar music with lyrics at a medium tempo generally yields high liking scores – particularly at low-to-moderate exercise intensities (see Karageorghis et al., 2008, 2011) – coupled with positive psychological responses, this is certainly not the case for unfamiliar/non-lyrical music (see Figure 3). The best tempo across all exercise intensities in terms of aesthetics and a range psychological responses (see Figure 3 and Figure 4), was of the fast variety. So, when unfamiliar music is used for an exercise task, perhaps in the context of an exercise class that attracts intergenerational participants, fast-tempo music is likely to engender the most positive responses.

From a research perspective, the present findings suggest stark differences in aesthetic and psychological responses between the familiar/lyrical music of past studies (e.g., Karageorghis et al., 2011) and unfamiliar/non-lyrical music. We used one music idiom (EDM) to ensure homogeneity across conditions, and so additional studies with other forms of unfamiliar/non-lyrical music appear warranted (e.g., rock and latin). It would also be worthwhile to single-out familiarity and the presence of lyrics with reference to preference for music tempo during exercise. We would then have better understanding of the relative importance of these two facets of music.

5. Conclusions

The findings of the present study point to stark differences in the exercise intensity–music-tempo preference relationship when the familiar, lyrical music examined in past studies (e.g., Karageorghis et al., 2006, 2011) is compared to unfamiliar, non-lyrical music. The focus of this study was on the latter and there was no discernible relationship between exercise intensity – established with reference to biological markers – and music-tempo preference (see Figure 1a and Figure 2). It seems that when music is unfamiliar and devoid of lyrics, it is generally fast, and very fast tempi that are suitable across a broad range of exercise intensities. The data were collected using young adult participants, and so the relationship when middle-aged or older adults are tested is presently unknown. This should be a focus of future research.

A secondary purpose of the present study was to gauge the meaningfulness or practical utility of the exercise intensity–music tempo preference relationship. Through examining a range of psychological and psychophysical variables (see Table 1), it emerged that the most positive psychological outcomes were generally associated with fast-tempo music (e.g., for affective valence and state attention). The fast-tempo condition (130 bpm) sat in the optimal range of music tempi identified in previous research (e.g., Karageorghis & Jones, 2014). The main practical implication to emerge from the present findings is that when exercisers or exercise professionals need to use unfamiliar, non-lyrical music, they should formulate playlists of tracks with fast-to-very-fast tempi (i.e., 130–150 bpm) across the gamut of exercise intensities. This optimal range is 10 bpm higher than that identified in previous work that tested familiar, lyrical music.

CRediT authorship contribution statement

L. Jones: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Resources, Software, Supervision, Visualization, Writing – original draft. **C.I. Karageorghis:** Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **T. Ker:** Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing. **C.J. Rushton:** Writing – review & editing, Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft. **S.R. Stephenson:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **I.L. Wheeldon:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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