See Hear: psychological effects of music and music-video during treadmill running

HUTCHINSON, Jasmin C., KARAGEORGHIS, Costas I. and JONES, Leighton <http://orcid.org/0000-0002-7899-4119>

Citation:

HUTCHINSON, Jasmin C., KARAGEORGHIS, Costas I. and JONES, Leighton (2015). See Hear: psychological effects of music and music-video during treadmill running. Annals of Behavioral Medicine, 49 (2), 199-211. [Article]

Running Head: MUSIC AND MUSIC-VIDEO DURING RUNNING

See Hear: Psychological Effects of Music and Music-Video during Treadmill Running

Jasmin C. Hutchinson,[1] Costas I. Karageorghis,[2] and Leighton Jones[2]

[1] Springfield College, Exercise Science and Sport Studies Department, Springfield, MA

[2] School of Sport and Education, Brunel University, UK

Acknowledgments

The authors would like to thank Alisha Ciolek, Paul Dalton, Jacob Ferreira, Elizabeth Hopley, Melanie Shepard, Nicholas Stodolski, and Christopher Williamson for their assistance with the data collection phase of this study.

Running Head: MUSIC AND MUSIC-VIDEO DURING RUNNING

See Hear: Psychological Effects of Music and Music-Video during Treadmill Running

Abstract

Background: There is a paucity of work addressing the distractive, affect-enhancing, and motivational influences of music and video in combination during exercise. *Purpose:* We examined the effects of music and music-and-video on a range of psychological and psychophysical variables during treadmill running at intensities above and below ventilatory threshold (VT). *Methods:* Participants (*N* = 24) exercised at 10% of maximal capacity below VT and 10% above under music-only, music-and-video, and control conditions. *Results:* There was a Condition x Intensity x Time interaction for perceived activation and state motivation, and an Intensity x Time interaction for state attention, RPE, and affective valence. The music-and-video condition elicited the highest levels of dissociation, lowest RPE, and most positive affective responses regardless of exercise intensity. *Conclusions:* Attentional manipulations influence psychological and psychophysical variables at exercise intensities above and below VT, and this effect is enhanced by the combined presentation of auditory and visual stimuli.

Keywords: Affective response, exercise, dissociation, dual-mode theory

Given the clear health benefits associated with aerobic-type exercise, one might expect that regular exercise participation would be highly pervasive in developed countries. Nonetheless, epidemiological data indicate that most American adults do not meet the recommended levels of exercise participation [1]. The problem of physical inactivity is complex and seemingly resistant to researcher and practitioner efforts to alter its course [2]. One of the most disconcerting aspects of the problem is the so-called "revolving door" phenomenon [3]; the observation that approximately 50% of the individuals who initiate a program of physical activity drop out within the first 6 months, and most within the first 3 months [4].

The exercise and health literature is replete with reasons for why people discontinue exercise (see [5] for a review) with scant attention given to the role of exercise-related affect [6, 7]. Following decades of research devoted to cognitive variables, such as self-efficacy and appraisals of social support to address the lack of adherence to physical activity, researchers are now also beginning to consider the role of affective variables, such as enjoyment and pleasure [2, 5]. Exercise intensities that are associated with significant cardiorespiratory gains can induce feelings of fatigue and negative affect [8]. This can act as a deterrent to continued participation and impact negatively on state motivation [9] (i.e., people do not wish to continue exercising when they experience negative affect; [10]). Given this potentially salient role of affective response to exercise, interventions that improve the exercise experience are likely to have a positive impact on exercise adherence, particularly if these effects persist at relatively high intensities [11].

Theoretical Backdrop

The dual-mode theory (DMT) of exercise-related affect [12] posits that affective responses during exercise are determined by the interplay between cognitive factors (perception and appraisal of sensory information, including attention) and interoceptive factors (e.g., acidosis, rise in core temperature). At lower intensities, cognitive factors are predicted to be most influential, while at higher intensities interoceptive factors are most influential. The critical turnpoint from lower to higher intensities is known as the *ventilatory threshold* (VT); this is the point during graded exercise at which pulmonary ventilation increases disproportionately relative to oxygen uptake. This breakpoint corresponds (but is not identical) to increasing blood lactate values and an increase in anaerobic metabolism.

Exercisers typically report pleasant feelings below VT and unpleasant feelings above it, whereas intensities that are proximal to VT elicit variable affective responses across individuals [2, 8, 13]. This inter-individual variability is presumed to reflect individual differences in the modulation of sensory information (e.g., differences in tolerance) as well as differences in the use of cognitive strategies for dealing with the physical challenge (e.g., attentional dissociation). When an intense bout of physical activity is ended, there is an immediate and pronounced affective *rebound* from negativity to positivity [14]. It is conceivable that pleasant and/or distractive stimuli presented during exercise (e.g., music-video) might reduce the magnitude of this rebound given that affective valence is maintained at a higher level throughout the exercise bout [15, 16].

As well as having a strong bearing on affective responses to exercise, VT also impacts upon attentional processes. For example, Hutchinson and Tenenbaum [17] identified an *attentional shift threshold* wherein attentional focus becomes increasingly internal beyond a critical exercise intensity (proximal to VT), as sensations of fatigue dominate focal awareness. Using an index of state attentional focus, recent research has shown that a single external stimulus (music) can delay the inevitable shift during high-intensity exercise by ~10% maximal heart rate reserve [18]. Nonetheless, it is not yet known whether multiple external stimuli are equally or even more effective in delaying this shift.

Enhancing the Exercise Experience

There is burgeoning empirical evidence to suggest that listening to music during exercise can significantly enhance the exercise experience in a variety of ways (see [19, 20] for a review). The proposed mechanisms that underlie the benefits of music in the exercise context embrace emotion regulation [21, 22], attentional narrowing [23], auditory-motor synchronization [24], and stimulation of the ascending reticular activating system [25]. The efficacy of music in enhancing core affect during exercise is seemingly independent of workload [26, 27]. This finding has important implications in terms of prescribing music as a means by which to enhance the exercise experience.

Recent work in the domains of psychomusicology and cognitive neuroscience has addressed the mechanisms that underlie the influence of music on core affect. For example, Juslin and Västfjäll [28] expounded the *brain stem reflex*, which refers to the process by which the fundamental acoustic properties of music stimulate responses by signaling a potentially important or urgent event. The stimulation increases perceived activation [29] and prompts elevated heart rate, blood pressure, body temperature, skin conductance, and muscle tension [30].

A series of recent studies has demonstrated that well-selected music can enhance state motivation and/or affective responses to exercise, even when exercise is conducted at a relatively high intensity [16, 23, 26, 31]. These findings serve to challenge the tenets of attentional theories that pertain to exercise such as the parallel processing model [32] and the load-dependent theory of effort perception and attentional focus [33]. In mechanistic terms, it is plausible that the processing of music during high-intensity exercise entails engagement of subcortical brain structures (e.g., the amygdala and cerebellum; [34, 35]) and thus does not require the higher-order processing that is severely inhibited by fatigue-related afferent feedback [32].

Affect and state motivation are closely related constructs; put in simple terms, how we feel about something directs our motivation toward it [36]. According to Lang and Bradley [37], feelings of pleasure/displeasure play a salient role in determining which motivational system is activated by a given stimulus event (i.e., appetitive or defensive): "…activation of these motive systems engages processes that facilitate attention allocation, information intake, sympathetic arousal, and, depending on context, will prompt tactical actions that can be directed either toward or away from the strategic goal" (p. 230). Thus, the affective experiences associated with exercise are likely to have a bearing on future participation decisions [11, 38, 39].

To date, there have been few studies that have examined the effects of music combined with video footage during exercise and none have assessed the affective response to exercise. Nevertheless, studies featuring a music-video condition reported benefits that were superior to those of music alone [40–42] suggesting that this is a potentially fruitful avenue for empirical investigation. Although Barwood et al. [40] reported beneficial effects of motivational music combined with video on treadmill running performance, a limitation in their design was that they did not include a condition that separated music from the video images. Lin and Lu [41] subsequently addressed this limitation, but yielded mixed results; a music-only condition had the largest effect on RPE, while the music-video combination had the largest effect on stationary cycling performance. In both studies, trials were conducted only at a high exercise intensity, which means that one cannot deduce the efficacy of the music-and-video intervention at low-to-moderate intensities.

Taking an ecologically valid approach and using members of a health club, Annesi [42] examined the influence of a range of distractive stimuli on exercise adherence over a 14-week period. He reported a trend toward greater adherence for a group of participants that was administered an intervention that included self-selected music combined with unrelated television images, when compared against groups exposed to music-only, television-only, and control conditions. There were significant methodological weaknesses evident in this study: (a) the duration of exercise was not standardized; (b) in the combined condition, the auditory and visual stimuli were incongruent; and (c) the sample size was limited, with only 11–14 participants per group. Given the pervasiveness of audio-visual entertainment systems in the health and fitness industry and the ad hoc manner in which they are used, there is a need for systematic scientific research that will enable health and exercise professionals to harness the potential benefits of such systems.

Rationale for the Present Study

We have established that exercise-related theories of affect [12], attention [33], and information processing [32] place emphasis on the moderating influence of exercise intensity in relation to the processing of external environmental cues (e.g., landscape, video, music) and internal fatigue-related cues (e.g., heart/respiration rate and muscle acidosis). According to such theories, at exercise intensities beyond VT, interoceptive cues demand greater levels of attention and processing due to the disturbance of the physiological steady-state, this renders external cues less influential in regard to moderating psychophysical indices such as perceived exertion. Moreover, given the internal bodily demands for attention, there is much less scope for *dissociation* (i.e., external and task-unrelated focus) and a compulsion toward *association* (i.e., internal and task-relevant focus) [17].

One important question that has yet to be addressed in the exercise domain is whether there is an additional attentional/processing demand when comparing a single stimulus, such as *asynchronous* or background music, and multiple external stimuli, such as the combination of music with video. Such a combination places demands on the auditory and visual processing systems and, as highlighted earlier, is highly representative of the distraction methods used in health and fitness facilities [20, 42].

It has been proposed by Rees, Frith, and Lavie [43] that "...the processing load of a relevant task determines the extent to which irrelevant distractors are processed" (p. 1616). A perceptual load that engages full processing capacity leaves no spare capacity for the perception of competing stimuli, such as those carried by the afferent nervous system during exercise [32]. Contrastingly, under conditions of low perceptual load, any spare capacity beyond that taken by the high-priority relevant stimuli is automatically allocated to extraneous stimuli. Thus, the potential effectiveness of a dissociative strategy is modulated by its perceptual load. Using this axiom, it is logical to predict that a plurality of external stimuli (e.g., music and video) during exercise should supersede a singular stimulus (e.g., music) in terms of a range of outcomes that are germane to the exercise experience (e.g., lower RPE, more positive affect, higher state motivation). This has meaningful implications for the proposed causal chain linking exercise intensity, affect, and exercise adherence [8].

Purpose and Hypotheses

The purpose of the present study was to examine the effects of external stimuli (music and music-video) on psychophysical and psychological variables (attentional focus, affective valence, perceived activation, and state motivation) at intensities 10% above and below ventilatory threshold (VT) during treadmill running. It was hypothesized that the music-and-video condition would lead to lower association/higher dissociation coupled with lower RPE scores, more pleasant affect, and higher activation and state motivation compared to music-only and control conditions (H_1). Moreover, the music-only condition would exhibit a similar pattern of differences to music-and-video on all dependent variables compared to control (H_2). The magnitude of the aforementioned effects was expected to be greater below VT, where there is greater scope for attentional manipulation [12, 33], than above VT (H_3).

The secondary purpose was to examine the effects of external stimuli on the intensity-affect relationship. Given the proposed association between attentional distraction and the emotional response to exercise [23], it was expected that state attention and in-task affect would exhibit a positive correlation (*H*$_4$). With reference to the importance of the exercise experience to post-task affective valance [6], it was hypothesized that there would be more positive post-exercise affect in the experimental conditions relative to control (*H*$_5$). Finally, the present analysis included time intervals within the exercise bout as an independent variable (minute 5, minute 10, and minute 15). No a priori hypotheses were set in relation to this variable and thus it was included to explore how participants would respond to musical and visual stimuli during the course of an exercise bout.

Methodology

Stage 1: Selection of Auditory and Visual Stimuli

Participants and procedure. A sample of 28 (M_{age} = 20.2 years, *SD* = 1.9 years) exercisers provided possible music selections for use in the experimental protocol of Stage 2. Given the salience of personal factors in determining music preference [44, 45], participants in each stage of the present study were similar in terms of age, race, and sociocultural background. Participants were asked to report their four favorite pieces of music for treadmill running. Subsequently, these selections were classified by tempo and 12 tracks of a similar tempo to that required for experimental testing (128-132 bpm; see [46]) that had an associated music video were subjected to further assessment.

A panel of 10 purposively selected exercise science majors (M_{age} = 19.8 years, *SD* = 1.2 years) rated the motivational qualities of the 12 tracks using the Brunel Music Rating Inventory-3 [47]. This procedure was undertaken to ensure that music used in the experimental trials was homogenous in terms of its motivational qualities (lyrical affirmations, extra-musical associations, etc.), as a lack of homogeneity can present a threat to internal validity. The panel rated the motivational qualities of each track with reference to running at a moderate-to-high intensity (5 out of 10 on the Borg CR10 scale [48]). Next, the panel evaluated the music video associated with each of the music tracks using the Affect Grid [49]. A video inclusion criterion was set wherein 90% of the panel had to deem their affective response to the music video to fall within the upper-right quadrant of the Affect Grid (i.e., “pleasant high arousal”).

Four tracks with similar motivational quotients (BMRI-3 scores of 30-32) that also met the video inclusion criterion were used in Stage 2 of the present study (*Memories* by David Guetta ft. Kid Cudi; *Good Feeling* by Flo Rida; *Let’s Go* by Calvin Harris ft. Neyo, and *I Can Only Imagine* by David Guetta ft. Chris Brown and Lil Wayne). The original video footage was edited (Final Cut Pro 7, Apple Inc.) to create a segued playlist of 15-min duration.

Stage 2: Experimental Investigation

Power analysis. A power analysis was undertaken using G*Power3 [50] to establish appropriate sample size. Based on a moderate predicted effect size ($f = .25$ [23]), an alpha level of .05, and power at .8 to protect beta at four times the level of alpha [51], the analysis indicated that 20 participants would be required. An extra four participants were recruited to protect against participant attrition and deletions due to outliers.

Participants. Twenty four habitually active [9] male (n = 14) and female (n = 10) participants (age, M±SD = 21.3±3.9 years; body mass index, M±SD = 23.55±2.14 m•kg^{-2}; VO_2 max, M±SD = 53.82±7.90 ml.kg^{-1}min^{-1}) volunteered to take part in this study. All were deemed sufficiently healthy for exercise according to a pre-exercise screening tool [9]. Participants were incentivized via an institutional scheme of professional development points that afforded them complete autonomy in terms of which projects they selected to become involved in. The study was approved by the Institutional Review Board of the first author, and procedures followed were in accordance with the Helsinki Declaration of 1975, as revised in 2000. All participants provided written informed consent.

Apparatus and measures. ***Experimental testing.*** Heart rate (HR) was monitored with a HR monitor (E600, Polar Electro Inc.) and respiratory values of oxygen consumed and carbon dioxide expired were measured with a metabolic cart (Sensor Medics 2900, Sensor Medics Corp.), which was calibrated with known gases before each use. A motorized treadmill (TRM 833, Precor Inc.) was used for experimental testing along with a wall-mounted stereo system (SC-PT75, Panasonic USA) and a decibel meter (407730, Extech Instruments) to standardize music intensity at 78 dbA. This sound intensity is advised by the National Institute for Occupational Safety and Health [52] as below that which might damage the hair cells in the inner ear. Video footage was played using a DVD player (Symphonic WF 803, Funai Corp.) connected to a ceiling-mounted projector (VT700, NEC Display Solutions). A projection screen (195 x 280 cm) was situated 3 m in front of the participant and the video images were projected onto it.

Measures. State attentional focus was assessed using Tammen's [53] single-item Attention Scale. The attention scale ranges from 0 to 100, with "0" representing a completely internal focus of attention (i.e., association; e.g., heart rate, muscular fatigue, breathing) and "100" representing a completely external focus (i.e., dissociation; e.g., daydreaming, environment, distractions). Tammen found the one-item scale to be both an efficient and valid measure of attention during running [53]. Ratings of perceived exertion were taken using Borg's RPE Scale with ratio properties [48]. Borg's RPE scale has been found to have high reliability for intra-test ($r = .83$) and retest ($r = .83$ to .94) measures and is an accurate indicator of physical discomfort [54, 55].

Affective valence (pleasure-displeasure) and perceived activation were assessed using the Feeling Scale (FS) [56] and Felt Arousal Scale (FAS) [57], respectively. The FS is an 11-point rating scale, ranging from (I feel) 'very good' (+5) to 'very bad'(-5). The authors of the FS demonstrated its validity in a series of three studies that are detailed in their original paper

[56]. The FAS is a six-point, single-item measure of perceived activation. The scale ranges from 1 to 6, with anchors at 1 (Low Arousal) and 6 (High Arousal). The FAS has exhibited correlations in the range .45 to.70 with the arousal scale of the Self-assessment Manikin and .47 to.65 with the arousal scale of the Affect Grid [8]. State motivation (SM) was assessed using a 10-point state motivation scale [58]. Motivation was defined at the *situational* level, which refers to the motivation one experiences while engaging in a particular activity [59]. The scale was anchored by 0 (*Not at all motivated*) and 10 (*Extremely motivated*), based on a “how do you feel right now” response set. Tenenbaum et al. [58] provided a strong rationale for the applicability of single-item scales where they demonstrate high face validity.

Procedure. Participants completed a total of eight laboratory sessions: An initial incremental exercise test, to determine maximal oxygen uptake (VO_2 max) ventilatory threshold, a habituation session, and six subsequent experimental trials. Participants ran at velocities corresponding to 10% of maximum capacity above and below VT during the experimental trials. Pilot testing indicated that participants were able to maintain exercise for the necessary duration at 10% above VT.

***Pretest and habituation*.** The first test consisted of a modified (ramp protocol) incremental exercise test [60]. The treadmill test was terminated at the point of volitional exhaustion and maximal oxygen uptake (VO_2 max) was verified using standard criteria [9]. All participants demonstrated at least two of the following three criteria: (a) terminal respiratory exchange ratio (RER) greater than 1.10; (b) 95% or greater of the age-predicted maximal heart rate (HR = 220 – age); and (c) a plateau in VO_2 with increasing workload. The highest level of oxygen uptake, averaged over 20 s, was designated as VO_2 max. VT was identified using the ventilatory equivalent for VO_2 method [61, 62]. The speed and grade corresponding with 10% of maximum capacity above and below VT for each participant were determined by plotting the treadmill protocol against VO_2 from each participant’s pretest data and interpolating the target treadmill speed and grade. A target HR corresponding with 10% above (*M* = 181.5, *SD* = 8.7 bpm) and below (*M* = 148.4, *SD* = 7.1 bpm) VT was also calculated for each participant from the pre-test data by plotting HR against VO_2.

Each participant completed a habituation session within 48 hr of the pretest. They were required to run at each target velocity and grade until steady state was achieved. HR and VO_2 were monitored throughout, and adjusted when necessary, to ensure the conditions elicited the desired exercise intensity (±3 bpm) for intensities above and below VT.

Experimental trials. There were two experimental conditions (music-only and music-and-video) and one control condition (no music and visually sterile) at 10% of maximum capacity above and below VT (six conditions in total). In the music-only condition, each participant was exposed to a 15-min playlist while immersed in a visually sterile environment. In the music-and-video condition, each participant was exposed to a 15-min music playlist that was accompanied by the associated music videos. The order of music tracks for the music-only condition and the order of music-videos for the music-and-video condition was randomized to negate the influence of any singular track/music video.

Upon arrival at the laboratory, baseline affective valance was collected and each participant was fitted with a HR monitor. Once the integrity of the HR signal was established, participants were led through a 5-min dynamic warm-up using a brief series of active stretches. This was followed by a 3-min walk on the treadmill at 3 mph. Participants were briefed on the experimental protocol and afforded an opportunity to ask questions. The treadmill was then set at the predetermined speed (mph) and grade to correspond with either 10% of maximum capacity above or below VT for each individual to commence the test. In-task measures (state attentional focus, RPE, FS, FAS, and state motivation) were taken just prior to minutes 5, 10, and 15 min of each condition. Upon completion of each testing bout, the researcher gradually reduced the velocity of the treadmill belt to 2.0-2.5 mph and the participant completed a 3-min cool-down. Following this, the participant dismounted the treadmill and sat to complete the posttask measure of affective valance.

Participants were requested to follow similar patterns of activity (including no vigorous physical activity) and diet on the day of each experimental trial [63]. The six experimental trials were scheduled at the same time of day for each participant over a 3-week period, with 48-72 hr between each trial. The order of testing conditions was counterbalanced using a Latin square table to minimize potential order and learning effects.

Data Analysis

Data were screened for univariate and multivariate outliers then tested for the parametric assumptions that underlie mixed-model ANOVA and MANOVA. The attention and psychophysical variables (state attention and RPE) were assessed using a 3 (Condition) x 2 (Intensity) x 3 (Time) MANOVA, as were in-task affective variables (affective valence and perceived activation scores). State motivation was assessed using a 3 (Condition) x 2 (Intensity) x 3 (Time) ANOVA. Significant omnibus statistics were followed by *F* tests that were Greenhouse-Geisser adjusted where necessary. These were supplemented by Bonferroni-adjusted pairwise-comparisons.

A 3 (Condition) x 2 (Intensity) x 3 (Time: baseline, during, posttask) mixed-model ANOVA was computed to examine affective responses across the entire bout of exercise. To facilitate the independent variable of time, the in-task valence scores were averaged and compared against baseline and posttask valence scores. To ascertain whether state attention was associated with in-task affective valence, Pearson’s product moment correlations were computed.

Results

Prior to the main analyses, data were checked for univariate outliers, of which there were two that were suitably adjusted (see [64], pp. 107-111). One case exhibited multiple univariate outliers and was thus removed from the dataset. No multivariate outliers were identified. Tests of the distributional properties of the data in each cell of the analysis revealed minor violations of normality in 5 of the 124 cells (all at $p < .05$). Tabachnick and Fidell [64] suggest that the F test is sufficiently robust to withstand such minor violations of normality. Collectively, the diagnostic tests indicated that the assumptions underlying mixed-model ANOVA and MANOVA were satisfactorily met. In the interests of parsimony and given the complexity of the analyses, only significant omnibus and univariate statistics are presented herein.

Attention and Psychophysical Variables

There was just one significant interaction effect (see Table 1), which was for Intensity x Time and this applied to both state attention ($p = .006$) and RPE ($p < .001$). In the case of state attention, there was stability in the scores across time at the below-VT intensity, and a gradual decline in dissociation/increase in association at the above-VT intensity from minute 5 to minute 15. The RPE results exhibit a similar profile to those for state attention given that there was relative stability in these scores at the below-VT intensity, and an increase in RPE at the above-VT intensity (see Figure 1).

There were three main effects for the psychophysical and attentional variables that spanned the independent variables of condition, intensity, and time (see Table 1). For condition, the RPE scores in the music-and-video condition were significantly ($p = .008$) lower than those in control ($M_{\text{diff}} = .39$, $SD = .52$), while the state attention scores revealed differences among all three conditions (all $p < .01$). The music-and-video condition yielded the highest level of dissociation ($M = 75.92$, $SD = 10.55$), followed by the music-only condition ($M = 67.20$, $SD = 13.09$), and control ($M = 52.86$, $SD = 16.45$). For intensity, there were significantly ($p < .001$) higher RPE scores and a higher degree of association at the above-VT intensity, when compared to below-VT. For time, there was a strong effect evident for RPE ($p < .001$; $\eta_p^2 = .71$), wherein ratings increased from minute 5 to minute 15.

Affective Variables

In-task. There was a higher-order interaction for perceived activation (Condition x Intensity x Time; see Table 1) wherein there was an increase in perceived activation when minute 5 was compared to minute 10 and minute 15 in the experimental conditions below VT, but not control. At the above VT intensity, perceived activation was higher in the experimental conditions than control for the first 10 minutes of the task. There was also a twoway interaction for affective valence (Intensity x Time; see Table 1) wherein at minute 15 at the above-VT intensity, there was a significant ($p = .025$) decline in valence when compared to the corresponding time point at the below-VT intensity.

There was a main effect of condition for both affective valence and perceived activation, as well as a main effect of intensity for affective valence and a main effect of time for perceived activation (Table 1). The condition main effect exhibited an identical pattern of differences across both variables, wherein the music-and-video condition elicited the highest scores followed by the music-only condition and control (all $p < .01$). The intensity main effect indicated that the lowest affective valence scores were recorded at the above-VT intensity ($p = .049$). The time main effect indicated that perceived activation increased significantly from minute 5 to 10 and from minute 5 to 15 (both $p < .001$), as well as from minute 10 to 15 ($p = .035$).

Pre- to posttask. There was a higher-order (threeway) interaction (see Table 1) wherein posttask affective valence was significantly higher at the below-VT intensity following exposure to the experimental conditions when compared to control ($M_{\text{diff}} = .56$, $SD = 1.20$, and $M_{\text{diff}} = .85$, $SD = 1.19$ for music and music-and-video respectively). However, this effect was not evident at the above-VT intensity, where there was a large decline in affect followed by a strong rebound in the control condition when compared to the music and music-and-video conditions (see Figure 2).

A main effect of time indicated that post-task affective valence was higher than in-task ($p < .001$; $M_{\text{diff}} = 1.07$, $SD = .48$). A main effect of condition showed that both experimental conditions were associated with greater positive affect than control ($p < .001$; $M_{\text{diff}} = 72$, $SD = .48$, and $M_{\text{diff}} = .95$, $SD = .91$ for music and music-and-video respectively).

State Motivation

There was a higher-order interaction for state motivation (Condition x Intensity x Time; see Table 1) wherein motivation increased from minute 5 to minute 10 in the experimental conditions at the below VT intensity, but not in the control condition. Conversely there was stability in motivation scores in the experimental conditions at the above VT intensity, while motivation increased slightly toward the end of the control condition. There was a main effect of condition for state motivation wherein the two experimental conditions yielded significantly ($p < .01$) higher motivation scores than control.

Correlations between State Attention and In-task Affective Valence

State attention scores (averaged over time) were positively correlated with in-task affective valence (averaged over time) at both intensities in the experimental conditions only (below-VT music-and-video, $r = .49$, $p = .009$, music-only, $r = .40$, $p = .030$; above-VT music-and-video, $r = .59$, $p = .001$, music-only, $r = .55$, $p = .003$). Conversely, the correlations were nonsignificant during the control conditions (below-VT, $r = .04$, $p = .862$; above-VT, $r = .23$, $p = .293$).

Discussion

The main purpose of this study was to examine the effects of auditory and visual stimuli on a range of psychological and psychophysical variables (attentional focus, RPE, affective valence, perceived activation, and state motivation) at intensities below and above the ventilatory threshold during treadmill running. A secondary purpose was to examine the effects of auditory and visual stimuli on affective valance across the entire exercise session and to explore the relationship between state attention and in-task affective valance.

Attention and Psychophysical Variables

H_1 and H_2 pertaining to differences among the music-and-video, music-only, and control conditions were fully supported for state attention and partially supported in the case of RPE. The state attention data indicate that at both exercise intensities the combination of music and video elicited the highest level of dissociation, followed by music-only, and control. This finding is consistent with the notion that the effectiveness of a dissociative strategy is modulated by its perceptual load [43]. Increased dissociation from internal fatigue-related stimuli was expected to manifest in terms of lower RPE scores. In the music-and-video condition, RPE scores were lower than those in control, but there was no significant difference between the two experimental conditions, or between music-only and control. This finding indicates that the dissociative effect of the music-only condition was not sufficient to have a significant effect on RPE. This lends support to the notion that the efficacy of multiple external stimuli should be superior to that of a singular stimulus during exercise [30, 42]. Feelings of discomfort have been identified as a significant barrier to regular exercise participation among the general population [65]; thus given that the combined stimuli of music and video have the capacity to reduce perceived exertion at moderate-to-high exercise intensities, it is plausible that such interventions would go some way toward improving adherence to exercise.

The anticipated Condition x Intensity interaction (H_3) did not emerge for either variable, indicating that the influence of music and music-video on state attention and RPE during treadmill running does not appear to be moderated by task intensity. This finding is inconsistent with Tenenbaum’s [33] load-dependent theory of effort perception and attentional focus. The theory predicts that at low-to-moderate exercise intensities, an exerciser's RPE can be moderated by external cues, but this does not hold during high-intensity exercise. In the present study, the combined stimuli of music and video were seemingly able to capture participants' attention and reduce their RPE at intensities above and below VT. This is the first experimental study to date that has tested the combination of auditory and visual stimuli at running intensities above and below VT. Therefore, it is possible that this combination of external stimuli might have been sufficiently engaging, from an information processing perspective, to extend the physiological parameters at which exercise participants gain meaningful psychophysical and attentional benefits [43]. This novel finding is consistent with field-based research demonstrating the superiority of combined entertainment (music and television) when compared to music only, TV only, or control on measures of exercise duration, cardiorespiratory fitness, and exercise adherence [42].

The Intensity x Time interaction for RPE is indicative of the physiological differences between steady-state exercise (below-VT)—where there is a balance between the demands placed on a body and the physiological response to those demands—and high-intensity exercise (above VT). At the above VT intensity there is greater reliance on the anaerobic energy system, resulting in an accumulation of fatigue and increased attention given to afferent cues [14].

The main effects of intensity and condition for state attention are consistent with previous research [17, 23, 66] that has demonstrated an "attentional shift" from dissociative to associative attentional focus with increasing task intensity. In the present study, there was a strong shift toward association above VT, with a mean difference of 15 units (scale range: 0–100) between the low and high exercise intensities. The current findings also support Terry and Karageorghis' [67] conceptual framework regarding the benefits of music in sport and exercise contexts, wherein dissociation from unpleasant feelings is identified as one of the potential benefits of music listening during exercise.

Affective Variables

In-task. H_1 and H_2 were supported by the present findings in relation to the affective variables, although no significant Condition x Intensity interaction emerged, therefore H_3 was not supported. Previous research has indicated that carefully selected music can positively influence affective responses to high-intensity exercise [16, 23, 26, 27, 31]. Therefore, the finding that music and music-and-video both positively influence affective response above VT is not entirely surprising, even though it is not consistent with theoretical predictions [12]. The finding also provides evidence in support of the proposed mechanism concerning the influence of music on subcortical brain structures that obviates the requirement for higher-order processing [34, 35].

As with the state attention and RPE data, it appears that the combination of music and video in an exercise setting can extend the period during which exercisers are able to experience positive affect beyond the VT, such that the commonly observed decline in affective response [2, 8, 12] is delayed. Nevertheless, this effect may not endure for the duration of an exercise bout. The Intensity x Time interaction effect revealed a significant decline in affective valence at minute 15 of the above-VT run when compared to the corresponding time point at the below-VT intensity. Similar findings were reported by Hutchinson and Karageorghis [23] who concluded that the beneficial effects of music appeared to be short-lived when task demands were high. It is noteworthy, however, that the beneficial effects of music-only began to wane after 4-6 min of high-intensity treadmill running in the Hutchinson and Karageorghis study, whereas they persisted until minute 10 under the music-and-video condition in the present study (see Figure 1).

The higher-order interaction for perceived activation showed an increasing level of activation in the experimental conditions but not in control at the below VT intensity (see Figure 1). Ostensibly, participants derived some stimulation from the experimental conditions, which exceeded that engendered by the physical task alone. At the above VT intensity, perceived activation was initially higher in the experimental conditions than control, but as the run progressed, there was an increase in perceived activation in the control condition, such that at by the end point of the run no condition effect remained. This increase in activation during the above-VT control condition was likely due to sympathetic nervous system activation, which increases proportionally with exercise intensity. Moreover, the work of Berlyne [25] (pp. 61-74) would suggest that when the ascending reticular activating system is highly stimulated by a task such as high-intensity exercise, the organism does not appear to have a need for *additional* stimulation from music (see also [46]).

State attention and in-task affective valence. In line with H_4, state attention scores were positively correlated with in-task affective valence at both exercise intensities in the experimental conditions, but not control. This provides evidence for attentional manipulation as one of the underlying mechanisms by which music and music-and-video might improve affective valence during exercise [6, 19]. Correlations were stronger at the above VT intensity (r = .55–.59) than below VT (r = .40–.49). A plausible explanation for this is that above VT, the two experimental conditions had a stronger bearing on affective responses during the exercise bout than they did below VT. Specifically, it appears that these conditions engendered more positive affect at a workload that, according to the DMT [12], is associated with greater variability in affective responses. In line with DMT, cognitive cues are more salient at lower intensities of exercise, but above VT there is a stronger influence of interoceptive cues that influence the affective centers of the brain (i.e., the amygdala, anterior cyngulate, and insular cortex).

Post-task affective valence. When baseline and in-task affective valence were compared to post-task affective valence, there was a predictable post-task improvement and the experimental conditions were associated with more positive affect than the control; thus H_5 was supported. The significant Condition x Intensity x Time interaction effect (see Table 1) demonstrates that post-task affective valence can be influenced by the in-task affective experience, and that affective valence following exercise under control conditions does not rebound to the same level as that for music-and-video [8]. Thus, the choice of attentional stimuli during exercise may have important implications for post-exercise experience. This, in turn, may influence the decision to engage in future exercise bouts [11, 38, 39] and go some way toward addressing the pervasive "revolving door" phenomenon [4].

When above-VT was compared to below-VT, it was apparent that in the former, there was a strong rebound for affective valence that was not moderated by condition. This is consistent with Solomon's opponent process theory of motivation/emotion [69] that views emotions as pairs of opposites. Solomon describes a "hedonistic contrast" phenomenon (p. 691) in which the primary or initial reaction to an emotional event will be followed by an opposite secondary emotional state (the "opponent process"). This opposite emotion is likely to reemerge strongly once the primary process is quieted; hence the tendency to experience a burst of relief and pleasure after finishing a challenging task. In the exercise context, it has been suggested that "…the magnitude of the rebound is proportional to the extent of the negative [affective] shift during strenuous exercise" (p. 50) [14].

State Motivation

A main effect of condition for state motivation showed higher motivation in the experimental conditions compared to control; accordingly H_1 was supported. There was, however, no difference between music-only and control, and no Condition x Intensity interaction; thus H_2 and H_3 were not supported. The significant Condition x Intensity x Time interaction hints at the possibility that the participants, who were habitually active, were not sufficiently physically challenged by the below-VT intensity, and thus derived some motivational benefit during the progression of both experimental conditions (see Figure 1). In comparing exercise intensities in the control condition, participants appeared more motivated by the challenge imposed by the above-VT intensity. This finding can be interpreted with reference to flow theory [70], which posits that when the challenge in a situation is low and the skills of the performer are high, boredom and apathy can ensue.

Limitations and Future Directions

In the present study, the effect of music, a single stimulus, was compared against the combined stimuli of music and video. Thus video was not separated from music in this design (i.e., there was no video-only condition). The rationale for this entailed the distinct lack of ecological validity associated with watching a music video with no sound. Nevertheless, future researchers may wish to consider “standalone” visual stimuli as a potential exercise intervention (e.g., immersive countryside scenes). In addition, we did not measure participants’ responses to the experimental stimuli while they were at rest. This was because past research has shown that engagement in exercise bears a strong influence on how people respond to music [18, 46]. Future researchers might consider taking measures at rest in order to gauge the pleasantness/liking associated with auditory and visual stimuli. Such an approach might facilitate researchers in disentangling affective responses to the stimuli from the distractive influence of the stimuli during exercise.

The present sample was comprised of physically active young adults and thus the findings cannot be readily generalized to the wider population without replication using a participant demographic profile that is more broadly representative. The relationship between acute affective responses to exercise and longer-term adherence among previously sedentary individuals has received some recent empirical support [11, 38]. The manipulation of affect during exercise with stimuli such as music and video, particularly with “at risk” populations, is likely to be a fruitful scientific endeavor. It would also be worthwhile to assess whether the present findings can be applied at a group level through the use of a music-video intervention in a group exercise context (e.g., a cardiac rehabilitation class). The present participants ran in a laboratory in relative isolation and it is noteworthy that in most real-life exercise environments, there would be other exercisers present, with the potential to offer additional distraction or social support.

In the present study, participants ran at workloads corresponding with 10% below and 10% above VT. This facilitated a physiologically meaningful distinction between conditions and was representative of exercise intensities that have applicability in the field. In addition, the selection of the 10% below and 10% above VT enabled a stringent test of the hypotheses that emanate from Ekkekakis’ (2003) dual-mode theory, given that if the experimental stimuli were found to be effectual at 10% above VT, they would also be effectual at VT. It would have been illuminating to also consider exercise at VT, however the 11 laboratory visits required from participants to achieve this would have constituted an undue demand.

The aesthetic congruence of the music and video used in the combined-stimuli condition cannot always be replicated in health and fitness facilities; oftentimes people listen to their own music but are compelled to watch screens that project material that is entirely unrelated (e.g., news channels). Thus there is a need for studies to examine the efficacy of incongruent audio and visual stimuli in such settings. A further useful addition to this line of research would be to explore which types of video material are most effective. Such work might also be meaningfully extended in order to examine the degree of immersion that is required to optimize the effects of audiovisual stimuli during exercise. Can the positive findings reported herein be replicated using a smaller television screen that is more typical of health and fitness facilities? Might the findings be enhanced through use of a more immersive environment (e.g., using over-ear headphones vs. speakers)? A recent trend has been toward the use of instructor-led exercise programs that are delivered via smartphones and tablets (e.g., Fitness Buddy). There is the potential here to combine music interspersed with vocal encouragement, and video, in order to encourage the user to exercise at a place and time convenient to them. This approach would go some way toward addressing some of the common “consumer resistances” to structured exercise [5].

Conclusions

The present findings demonstrate that music combined with video can capture participants’ attention, reduce perceptions of exertion, enhance affective responses, and increase state motivation in an exercise setting. The mediating role of attentional focus was evidenced in the significant positive correlations between state attention and affective valence. Of particular practical and theoretical relevance is that fact that the aforementioned effects were observed not only during moderate (below-VT) exercise, but also during exercise that exceeded VT. The upper intensity employed in the present study is demonstrably capable of inducing an internal attentional shift with a corresponding decline in affective valence and state motivation; as was evident in the above-VT control condition. From a practical perspective, these results present empirical evidence to support the efficacy of music-and-video as an easily implementable strategy for improving the exercise experience. This has particular relevance for novice exercisers who may lack the experience and/or ability to self-regulate exercise intensity to maximize pleasure, or for deconditioned individuals for whom even “light” [9] exercise would exceed ventilatory threshold [14]. The implications of this for public health are evidenced in the burgeoning data on the role of in-task affect [11, 38, 39] and enjoyment [7] in the promotion of habitual exercise.

References

1. Centers For Disease Control and Prevention. Behavioral Risk Factor Surveillance System Questionnaire. *System*. 2011;83(12):76. Available at: http://www.cdc.gov/brfss/questionnaires/english.htm

2. Ekkekakis P, Parfitt G, Petruzzello SJ. The pleasure and displeasure people feel when they exercise at different intensities: decennial update and progress towards a tripartite rationale for exercise intensity prescription. *Sport Med*. 2011;41(8):641-671. doi:10.2165/11590680-000000000-00000

3. Dishman RK. The Problem of Exercise Adherence: Fighting Sloth in Nations With Market Economies. *Quest*. 2001;53:279-294. doi:10.1080/00336297.2001.10491745

4. Dishman RK, Heath GW, Lee I-M. Physical Activity Epidemiology. *Phys Act Epidemiol 2nd ed*. 2013.

5. Rhodes RE, Warburton DER, Murray H. Characteristics of physical activity guidelines and their effect on adherence: a review of randomized trials. *Sport Med*. 2009;39:355-375. doi:10.2165/00007256-200939050-00003

6. Ekkekakis P, Hargreaves EA, Parfitt G. Invited Guest Editorial: Envisioning the next fifty years of research on the exercise-affect relationship. *Psychol Sport Exerc*. 2013;14:751-758. doi:10.1016/j.psychsport.2013.04.007

7. Rhodes RE, Fiala B, Conner M. A review and meta-analysis of affective judgments and physical activity in adult populations. *Ann Behav Med*. 2009;38:180-204. doi:10.1007/s12160-009-9147-y

8. Ekkekakis P, Hall EE, Petruzzello SJ. The relationship between exercise intensity and affective responses demystified: to crack the 40-year-old nut, replace the 40-year-old nutcracker! *Ann Behav Med*. 2008;35(2):136-149. doi:10.1007/s12160-008-9025-z

9. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription*. 9th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2013.

10. Parfitt G, Alrumh A, Rowlands AV. Affect-regulated exercise intensity: Does training at an intensity that feels 'good' improve physical health? *J Sci Med Sport*. 2012;15(6):548-553. doi:10.1016/j.jsams.2012.01.005

11. Williams DM, Dunsiger S, Ciccolo JT, Lewis BA, Albrecht AE, Marcus BH. Acute affective response to a moderate-intensity exercise stimulus predicts physical activity participation 6 and 12 months later. *Psychol Sport Exerc*. 2008;9:231-245. doi:10.1016/j.psychsport.2007.04.002

12. Ekkekakis P. Pleasure and displeasure from the body: Perspectives from exercise. *Cogn Emot*. 2003;17(2):213-239. doi:10.1080/02699930302292

13. Ekkekakis P, Hall EE, Petruzzello SJ. Variation and homogeneity in affective responses to physical activity of varying intensities: An alternative perspective on dose-response based on evolutionary considerations. *J Sports Sci*. 2005;23(5):477-500. doi:10.1080/02640410400021492

14. Ekkekakis P. Pleasure from the exercising body: Two centuries of changing outlooks in psychological thought. In: Ekkekakis P, ed. *Routledge Handbook of Physical Activity and Mental Health*. New York, NY: Routledge; 2013:35-56.

15. Boutcher SH, Trenske M. The effects of sensory deprivation and music on perceived exertion and affect during exercise. *J Sport Exerc Psychol*. 1990;12:167-176.

16. Karageorghis CI, Mouzourides D, Priest DL, Sasso T, Morrish D, Walley C. Psychophysical and ergogenic effects of synchronous music during treadmill walking. *J Sport Exerc Psychol*. 2009;31:18-36.

17. Hutchinson JC, Tenenbaum G. Attention focus during physical effort: The mediating role of task intensity. *Psychol Sport Exerc*. 2007;8(2):233-245. doi:10.1016/j.psychsport.2006.03.006

18. Karageorghis CI, Jones L. On the stability and relevance of the exercise heart rate-music-tempo preference relationship. *Psychol Sport Exerc*. 2014;15(3):299-310. doi:10.1016/j.psychsport.2013.08.004

19. Karageorghis CI, Priest D. Music in the exercise domain: A review and synthesis (Part I). *Int Rev Sport Exerc Psychol*. 2012;5(1):44-66. doi:10.1080/1750984X.2011.631026

20. Karageorghis CI, Priest DL. Music in the exercise domain: A review and synthesis (Part II). *Int Rev Sport Exerc Psychol*. 2012;5(1):67-84. doi:10.1080/1750984X.2011.631027

21. Scherer KR, Zentner MR. Emotional Effects of Music: Production Rules. In: Juslin PN, Sloboda JN, eds. *Music and Emotion: Theory and Research*. 2001:361-392.

22. Zentner M, Grandjean D, Scherer KR. Emotions evoked by the sound of music: characterization, classification, and measurement. *Emotion*. 2008;8(4):494-521. doi:10.1037/1528-3542.8.4.494

23. Hutchinson JC, Karageorghis CI. Moderating influence of dominant attentional style and exercise intensity on responses to asynchronous music. *J Sport Exerc Psychol*. 2013;35(6):625-43.

24. Large EW. On synchronizing movements to music. *Hum Mov Sci*. 2000;19:527-566. doi:10.1016/S0167-9457(00)00026-9

25. Berlyne D. *Aesthetics and Psychobiology*. New York, NY: Appleton Century Crofts; 1971.

26. Hutchinson JC, Sherman T, Davis L, Cawthon D, Reeder NB, Tenenbaum G. The influence of asynchronous motivational music on a supramaximal exercise bout. *Int J Sport Psychol*. 2011;42(2):135-148.

27. Terry PC, Karageorghis CI, Saha AM, D'Auria S. Effects of synchronous music on treadmill running among elite triathletes. *J Sci Med Sport*. 2012;15:52-57. doi:10.1016/j.jsams.2011.06.003

28. Juslin PN, Västfjäll D. Emotional responses to music: The need to consider underlying mechanisms. *Behav Brain Sci*. 2008;31:559-621. doi:10.1017/S0140525X08005293

29. Loizou G, Karageorghis CI. Video, priming and music: Effects on emotions and motivation. In: Bateman AJ, Bale JR, ed. *Sporting Sounds: Relationships between Sport and Music*. London: Routledge; 2009:37-58.

30. Chapados C, Levitin DJ. (2008). Cross-modal interactions in the experience of musical performance: Physiological correlates. *Cognition*. 2008;108;639-651. doi:10.1016/j.cognition.2008.05.008

31. Karageorghis CI, Hutchinson JC, Jones L, Farmer HL, Ayhan MS, Wilson RC, Rance J, Hepworth, CJ, Bailey SG. Psychological, psychophysical, and ergogenic effects of music in swimming. *Psychol Sport Exerc*. 2013;14:560-568. doi:10.1016/j.psychsport.2013.01.009

32. Rejeski WJ. Perceived exertion: An active or passive process? *J Sport Psychol*. 1985;7:371-378.

33. Tenenbaum G. A social-cognitive perspective of perceived exertion and exertion tolerance. In: Singer R, Hausenblas H, Janelle C, eds. *Handbook of Sport Psychology*. New York: Wiley; 2001:810-22.

34. LeDoux JE. *The Emotional Brain: The Mysterious Underpinnings of Emotional Life*. New York, NY: Simon & Schuster; 1996.

35. Levitin DJ, Tirovolas AK. Current advances in the cognitive neuroscience of music. *Ann NY Acad Sci*. 2009;1156:211-231. doi:10.1111/j.1749-6632.2009.04417.x

36. Rolls ET. On the brain and emotion. *Behav Brain Sci*. 2000;23(2):219-228. doi:10.1017/S0140525X00512424

37. Lang PJ, Bradley MM. Appetitive and defensive motivation: Goal-directed or goal-determined? *Emotion Rev*. 2013;5(3):230-234. doi:10.1177/1754073913477511

38. Williams DM, Dunsiger S, Jennings EG, Marcus BH. Does affective valence during and immediately following a 10-min walk predict concurrent and future physical activity? *Ann Behav Med*. 2012;44:43-51. doi:10.1007/s12160-012-9362-9

39. Kwan BM, Bryan A. In-task and post-task affective response to exercise: Translating exercise intentions into behaviour. *Brit J Health Psych.* 2010;15:115-131. doi:10.1348/135910709X433267

40. Barwood MJ, Weston NVJ, Thelwell R, Page J. A motivational music and video intervention improves high-intensity exercise performance. *J Sports Sci Med*. 2009;8:435-442.

41. Lin JH, Lu FJH. Interactive effects of visual and auditory intervention on physical performance and perceived exertion. *J Sports Sci Med*. 2013;12:388-393.

42. Annesi JJ. Effects of music , television , and a combination entertainment system on distraction , exercise adherence, and physical output in adults. *Can J Behav Sci*. 2001;33:193-201. doi: 10.1037/h0087141

43. Rees G, Frith CD, Lavie N. Modulating irrelevant motion perception by varying attentional load in an unrelated task. *Science*.1997;278:1616-1619. doi:10.1126/science.278.5343.1616.

44. Park M, Hennig-Fast K, Bao Y, et al. Personality traits modulate neural responses to emotions expressed in music. *Brain Res*. 2013;1523:68-76.

45. North AC. Music and Taste. In: North A, Hargreaves DJ, eds. *The Social and Applied Psychology of Music*. Oxford, UK: Oxford University Press; 2008:75–142.

46. Karageorghis CI, Jones L, Priest D-L, et al. Revisiting the relationship between exercise heart rate and music tempo preference. *Res Q Exerc Sport*. 2011;82(2):274-284. doi:10.1080/02701367.2011.10599755

47. Karageorghis CI. The scientific application of music in sport and exercise. In: Lane AM, ed. *Sport and Exercise Psychology Topics in Applied Psychology*. Hodder Education Group; 2008:109-137.

48. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc*. 1982;14:377-381. doi:10.1249/00005768-198205000-00012

49. Russell JA, Weiss A, Mendelsohn GA. Affect Grid: A single-item scale of pleasure and arousal. *J Pers Soc Psychol*. 1989;57:493-502. doi:10.1037/0022-3514.57.3.493

50. Faul F, Erdfelder E, Lang A, Buchner A. G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39(2):175-191. doi:10.3758/BF03193146

51. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale, NJ: Erlbaum; 1988.

52. National Institute for Occupational Safety and Health. *Preventing Occupational Hearing Loss - A Practical Guide*. Cincinnati, Ohio: DHHS(NIOSH) Publication No.96-110; 1996.

53. Tammen V. Elite middle and long distance runners associative/dissociative coping . *J Appl Sport Psychol*. 1996;8:1-8. doi:10.1080/10413209608406304

54. Borg GA. *Borg's Perceived Exertion and Pain Scales*. Champaign, IL: Human Kinetics; 1998.

55. Scherr J, Wolfarth B, Christle JW, Pressler A, Wagenpfeil S, Halle M. Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. *Eur J Appl Physiol*. 2012;113(1):147-155. doi:10.1007/s00421-012-2421-x

56. Hardy CJ, Rejeski WJ. Not what, but how one feels: The measurement of affect during exercise. *J Sport Exerc Psychol*. 1989;11:304-317.

57. Svebak S, Murgatroyd S. Metamotivational dominance: A multimethod validation of reversal theory constructs. *J Pers Soc Psychol*. 1985;48(1):107-116. doi:10.1037/0022-3514.48.1.107

58. Tenenbaum G, Kamata A, Hayashi K. Measurement in sport and exercise psychology: A new outlook on selected issues of reliability and validity. In: Tenenbaum G, Eklund R, eds. *Handbook of Sport Psychology*. 3rd ed. Hoboken, NJ: Wiley; 2007:757–773.

59. Vallerand RJ. Intrinsic and extrinsic motivation in sport and physical activity: A review and a look at the future. In: Tenenbaum G, Eklund R, eds. *Handbook of Sport Psychology*. 3rd ed. Hoboken, NJ: Wiley; 2007:59-83.

60. McConnell TR. Practical considerations in the testing of VO2max in runners. *Sport Med*. 1988;5(1):57-68.

61. Luks A, Glenny R, Robertson H. *Introduction to Cardiopulmonary Exercise Testing.* New York: Springer; 2013.

62. Reinhard U, Müller PH, Schmülling RM. Determination of anaerobic threshold by the ventilation equivalent in normal individuals. *Respiration*. 1979;38(1):36-42. doi:10.1159/000194056

63. Harris P. *Designing and Reporting Experiments in Psychology*. 3rd ed. Maidenhead, UK: Open University Press; 2008.

64. Tabachnick BG, Fidell LS. *Using Multivariate Statistics.* 3rd ed. Boston: Pearson; 2013.

65. Poulton R, Trevena J, Reeder AI Richards R. Physical health correlates of overprediction of physical discomfort during exercise. *Behav Res Ther*. 2002;40:401-414. doi:10.1016/S0005-7967(01)00019-5

66. Razon S, Basevitch I, Land W, Thompson B, Tenenbaum G. Perception of exertion and attention allocation as a function of visual and auditory conditions. *Psychol Sport Exerc*. 2009;10(6):636-643. doi:10.1016/j.psychsport.2009.03.007

67. Terry PC, Karageorghis CI. Psychophysical Effects of Music in Sport and Exercise : An Update on Theory , Research and Application. In: Katsikitis M, ed. *Proceedings of the 2006 Joint Conference of the Australian Psychological Society and the New Zealand Psychological Society*. Melbourne, Australia: Australian Psychological Society; 2006:415-419.

68. Lind E, Ekkekakis P, Vazou S. The affective impact of exercise intensity that slightly exceeds the preferred level: “pain” for no additional “gain”. *J Health Psychol*. 2008;13(4):464-468. doi:10.1177/1359105308088517

69. Solomon RL. The opponent-process theory of acquired motivation: The costs of pleasure and the benefits of pain. *Am Psychol*. 1980;35(8):691-712. doi: 10.1037/0003-066X.35.8.691

70. Csikszentmihalyi M. *Flow: The Psychology of Optimal Experience*. New York, NY: Harper & Row; 1990.

Table 1

Significant Inferential Statistics for all Dependent Variables

	Multivariate Results				
	Pillai's	*F*	*Df*	*p*	η_p^2
Psychophysical and Attention Variables					
Intensity x Time	.60	9.48	4, 88	< .001	.30
Intensity	.88	76.27	2, 21	< .001	.88
Condition	.55	8.39	4, 88	< .001	.28
Time	.72	71.68	4, 88	< .001	.36
Affective Variables					
Intensity x Condition x Time	.27	2.06	4, 88	.042	.09
Intensity x Time	.30	3.82	4,88	.007	.15
Intensity	.36	5.89	2, 21	.009	.36
Condition	.51	7.36	4, 88	< .001	.25
Time	.52	7.61	4, 88	< .001	.26
	Univariate Results				
		F	*Df*	*p*	η_p^2
State Attentional Focus					
Intensity x Time		5.69	2, 44	.006	.21
Condition		22.66	1.52, 31.99	< .001	.51
Intensity		55.21	1, 22	< .001	.72
Time		5.44	1.26, 26.53	.008	.20
Ratings of Perceived Exertion					
Intensity x Time		29.60	2, 44	< .001	.57
Condition		4.54	1.36, 29.92	.016	.17
Intensity		115.60	1, 22	< .001	.84
Time		54.69	1.52, 27.30	< .001	.71
Affective Valance					
Intensity x Time		5.47	2, 44	.008	.20
Intensity		5.99	1, 22	.023	.21
Condition		17.81	1.23, 27.09	< .001	.45
Perceived Activation					
Intensity x Condition x Time		3.70	4, 88	.008	.14
Intensity		6.98	1, 22	.015	.24
Condition		15.50	1.36, 27.10	< .001	.41
Time		21.83	2, 44	< .001	.50
Affective Valance (baseline, during, posttask)					
Intensity x Condition x Time		2.71	4,88	.034	.11
Intensity x Time		15.61	2,44	< .001	.42
Condition x Time		9.47	4,88	< .001	.30
Condition		6.26	1.33, 29.28	.004	.22
Time		18.86	2,44	< .001	.46
State Motivation					
Intensity x Condition x Time		3.29	4, 88	.014	.13
Condition		16.91	1.50, 32.92	< .001	.44
Time		4.59	1.46, 32.04	.016	.17

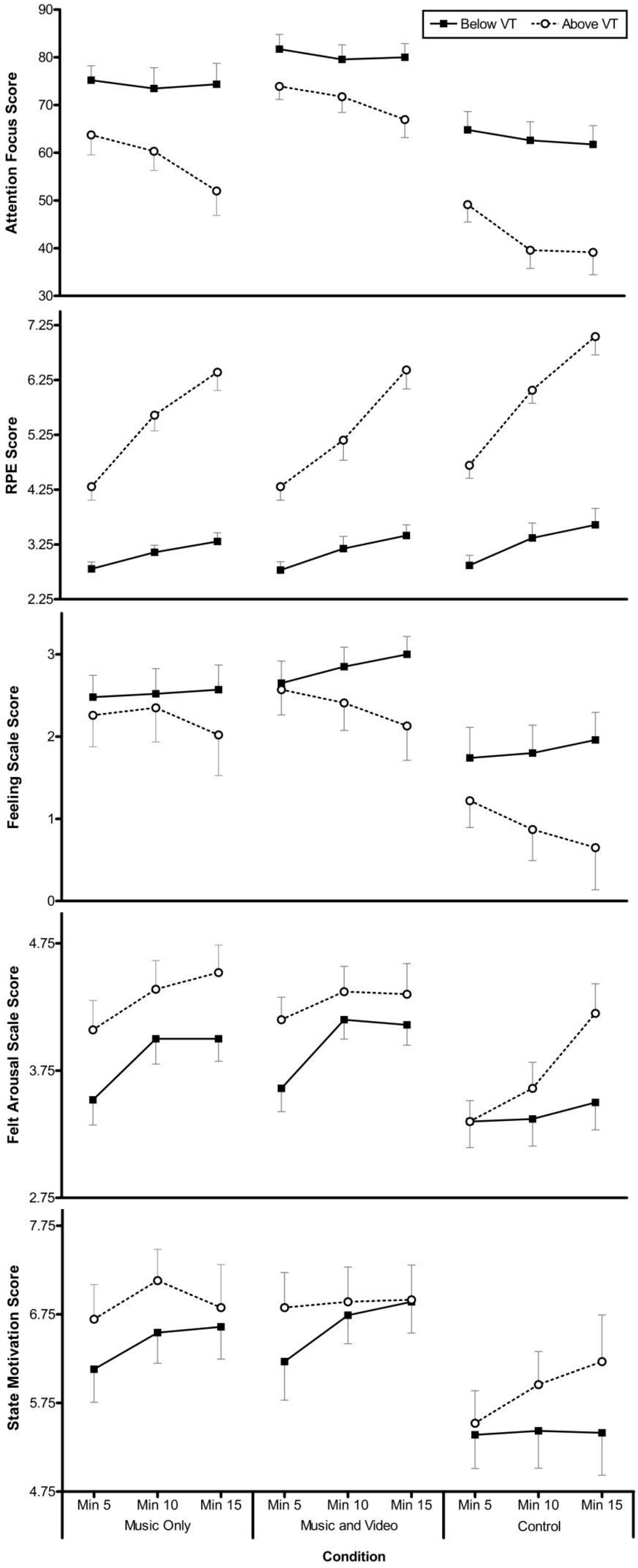

Figure 1. Condition x Intensity x Time interaction for all dependent variables.

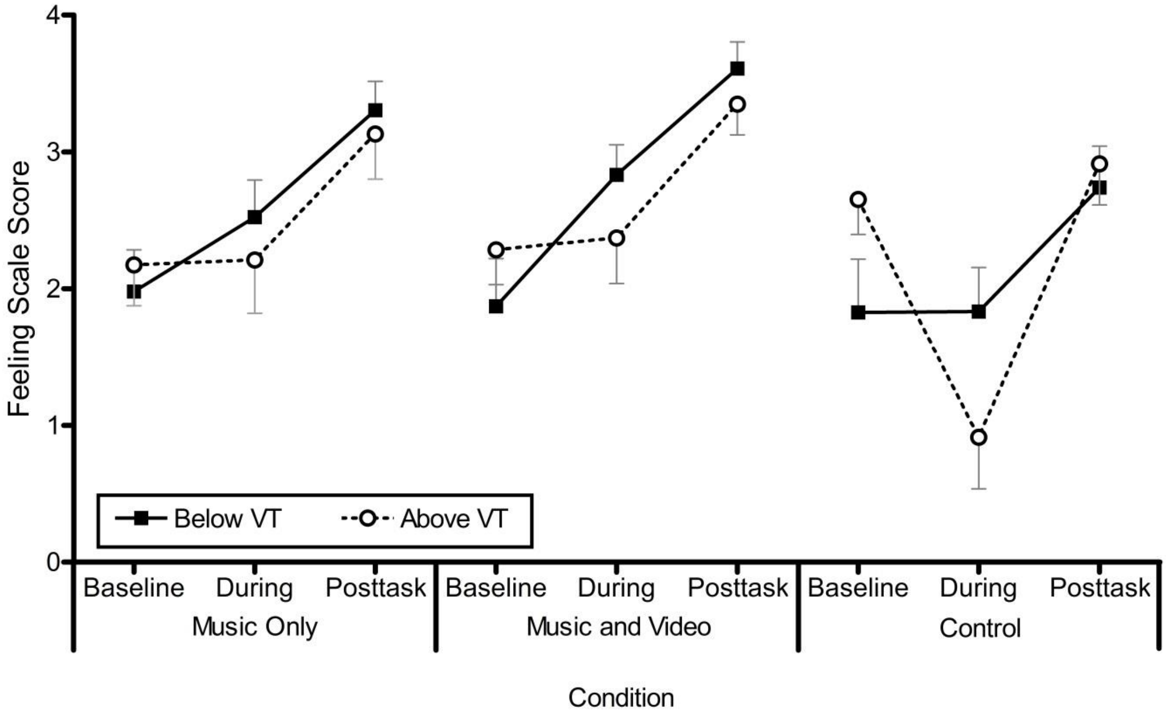

Figure 2. Condition x Intensity x Time interaction for affective valence.