

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

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Running Head: MUSIC AND MUSIC-VIDEO DURING RUNNING

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

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1 Running Head: MUSIC AND MUSIC-VIDEO DURING RUNNING

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

7 Running

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## 1 Abstract

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

15

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

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

10           The exercise and health literature is replete with reasons for why people discontinue  
11 exercise (see [5] for a review) with scant attention given to the role of exercise-related affect  
12 [6, 7]. Following decades of research devoted to cognitive variables, such as self-efficacy and  
13 appraisals of social support to address the lack of adherence to physical activity, researchers  
14 are now also beginning to consider the role of affective variables, such as enjoyment and  
15 pleasure [2, 5]. Exercise intensities that are associated with significant cardiorespiratory gains  
16 can induce feelings of fatigue and negative affect [8]. This can act as a deterrent to continued  
17 participation and impact negatively on state motivation [9] (i.e., people do not wish to  
18 continue exercising when they experience negative affect; [10]). Given this potentially salient  
19 role of affective response to exercise, interventions that improve the exercise experience are  
20 likely to have a positive impact on exercise adherence, particularly if these effects persist at  
21 relatively high intensities [11].

## 22 **Theoretical Backdrop**

23           The dual-mode theory (DMT) of exercise-related affect [12] posits that affective  
24 responses during exercise are determined by the interplay between cognitive factors  
25 (perception and appraisal of sensory information, including attention) and interoceptive

1 factors (e.g., acidosis, rise in core temperature). At lower intensities, cognitive factors are  
2 predicted to be most influential, while at higher intensities interoceptive factors are most  
3 influential. The critical turnpoint from lower to higher intensities is known as the ventilatory  
4 threshold (VT); this is the point during graded exercise at which pulmonary ventilation  
5 increases disproportionately relative to oxygen uptake. This breakpoint corresponds (but is  
6 not identical) to increasing blood lactate values and an increase in anaerobic metabolism.

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

17         As well as having a strong bearing on affective responses to exercise, VT also impacts  
18 upon attentional processes. For example, Hutchinson and Tenenbaum [17] identified an  
19 attentional shift threshold wherein attentional focus becomes increasingly internal beyond a  
20 critical exercise intensity (proximal to VT), as sensations of fatigue dominate focal  
21 awareness. Using an index of state attentional focus, recent research has shown that a single  
22 external stimulus (music) can delay the inevitable shift during high-intensity exercise by  
23 ~10% maximal heart rate reserve [18]. Nonetheless, it is not yet known whether multiple  
24 external stimuli are equally or even more effective in delaying this shift.

25

## 1 **Enhancing the Exercise Experience**

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

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

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

1           Affect and state motivation are closely related constructs; put in simple terms, how we  
2 feel about something directs our motivation toward it [36]. According to Lang and Bradley  
3 [37], feelings of pleasure/displeasure play a salient role in determining which motivational  
4 system is activated by a given stimulus event (i.e., appetitive or defensive): "...activation of  
5 these motive systems engages processes that facilitate attention allocation, information  
6 intake, sympathetic arousal, and, depending on context, will prompt tactical actions that can  
7 be directed either toward or away from the strategic goal" (p. 230). Thus, the affective  
8 experiences associated with exercise are likely to have a bearing on future participation  
9 decisions [11, 38, 39].

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

22           Taking an ecologically valid approach and using members of a health club, Annesi  
23 [42] examined the influence of a range of distractive stimuli on exercise adherence over a 14-  
24 week period. He reported a trend toward greater adherence for a group of participants that  
25 was administered an intervention that included self-selected music combined with unrelated



1 television images, when compared against groups exposed to music-only, television-only,  
2 and control conditions. There were significant methodological weaknesses evident in this  
3 study: (a) the duration of exercise was not standardized; (b) in the combined condition, the  
4 auditory and visual stimuli were incongruent; and (c) the sample size was limited, with only  
5 11–14 participants per group. Given the pervasiveness of audio-visual entertainment systems  
6 in the health and fitness industry and the ad hoc manner in which they are used, there is a  
7 need for systematic scientific research that will enable health and exercise professionals to  
8 harness the potential benefits of such systems.

### 9 **Rationale for the Present Study**

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

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

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

### 13 **Purpose and Hypotheses**

14           The purpose of the present study was to examine the effects of external stimuli (music  
15 and music-video) on psychophysical and psychological variables (attentional focus, affective  
16 valence, perceived activation, and state motivation) at intensities 10% above and below  
17 ventilatory threshold (VT) during treadmill running. It was hypothesized that the music-and-  
18 video condition would lead to lower association/higher dissociation coupled with  
19 lower RPE scores, more pleasant affect, and higher activation and state motivation compared  
20 to music-only and control conditions (H<sub>1</sub>). Moreover, the music-only condition would exhibit  
21 a similar pattern of differences to music-and-video on all dependent variables compared to  
22 control (H<sub>2</sub>). The magnitude of the aforementioned effects was expected to be greater below  
23 VT, where there is greater scope for attentional manipulation [12, 33], than above VT (H<sub>3</sub>).

24           The secondary purpose was to examine the effects of external stimuli on the intensity-  
25 affect relationship. Given the proposed association between attentional distraction and the

1 emotional response to exercise [23], it was expected that state attention and in-task affect  
2 would exhibit a positive correlation ( $H_4$ ). With reference to the importance of the exercise  
3 experience to post-task affective valance [6], it was hypothesized that there would be more  
4 positive post-exercise affect in the experimental conditions relative to control ( $H_5$ ). Finally,  
5 the present analysis included time intervals within the exercise bout as an independent  
6 variable (minute 5, minute 10, and minute 15). No a priori hypotheses were set in relation to  
7 this variable and thus it was included to explore how participants would respond to musical  
8 and visual stimuli during the course of an exercise bout.

## 9 **Methodology**

### 10 **Stage 1: Selection of Auditory and Visual Stimuli**

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

19 A panel of 10 purposively selected exercise science majors ( $M_{\text{age}} = 19.8$  years,  $SD =$   
20 1.2 years) rated the motivational qualities of the 12 tracks using the Brunel Music Rating  
21 Inventory-3 [47]. This procedure was undertaken to ensure that music used in the  
22 experimental trials was homogenous in terms of its motivational qualities (lyrical  
23 affirmations, extra-musical associations, etc.), as a lack of homogeneity can present a threat  
24 to internal validity. The panel rated the motivational qualities of each track with reference to  
25 running at a moderate-to-high intensity (5 out of 10 on the Borg CR10 scale [48]). Next, the

1 panel evaluated the music video associated with each of the music tracks using the Affect  
2 Grid [49]. A video inclusion criterion was set wherein 90% of the panel had to deem their  
3 affective response to the music video to fall within the upper-right quadrant of the Affect  
4 Grid (i.e., “pleasant high arousal”).

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

## 11 **Stage 2: Experimental Investigation**

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

17 **Participants.** Twenty four habitually active [9] male ( $n = 14$ ) and female ( $n = 10$ )  
18 participants (age,  $M \pm SD = 21.3 \pm 3.9$  years; body mass index,  $M \pm SD = 23.55 \pm 2.14 \text{ m} \cdot \text{kg}^{-2}$ ;  
19  $\text{VO}_2 \text{ max}$ ,  $M \pm SD = 53.82 \pm 7.90 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) volunteered to take part in this study. All were  
20 deemed sufficiently healthy for exercise according to a pre-exercise screening tool [9].  
21 Participants were incentivized via an institutional scheme of professional development points  
22 that afforded them complete autonomy in terms of which projects they selected to become  
23 involved in. The study was approved by the Institutional Review Board of the first author,  
24 and procedures followed were in accordance with the Helsinki Declaration of 1975, as  
25 revised in 2000. All participants provided written informed consent.

1           **Apparatus and measures. Experimental testing.** Heart rate (HR) was monitored  
2 with a HR monitor (E600, Polar Electro Inc.) and respiratory values of oxygen consumed and  
3 carbon dioxide expired were measured with a metabolic cart (Sensor Medics 2900, Sensor  
4 Medics Corp.), which was calibrated with known gases before each use. A motorized  
5 treadmill (TRM 833, Precor Inc.) was used for experimental testing along with a wall-  
6 mounted stereo system (SC-PT75, Panasonic USA) and a decibel meter (407730, Extech  
7 Instruments) to standardize music intensity at 78 dbA. This sound intensity is advised by the  
8 National Institute for Occupational Safety and Health [52] as below that which might damage  
9 the hair cells in the inner ear. Video footage was played using a DVD player (Symphonic WF  
10 803, Funai Corp.) connected to a ceiling-mounted projector (VT700, NEC Display  
11 Solutions). A projection screen (195 x 280 cm) was situated 3 m in front of the participant  
12 and the video images were projected onto it.

13           **Measures.** State attentional focus was assessed using Tammen's [53] single-item  
14 Attention Scale. The attention scale ranges from 0 to 100, with "0" representing a completely  
15 internal focus of attention (i.e., association; e.g., heart rate, muscular fatigue, breathing) and  
16 "100" representing a completely external focus (i.e., dissociation; e.g., daydreaming,  
17 environment, distractions). Tammen found the one-item scale to be both an efficient and  
18 valid measure of attention during running [53]. Ratings of perceived exertion were taken  
19 using Borg's RPE Scale with ratio properties [48]. Borg's RPE scale has been found to have  
20 high reliability for intra-test ( $r = .83$ ) and retest ( $r = .83$  to  $.94$ ) measures and is an accurate  
21 indicator of physical discomfort [54, 55].

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

1 [56]. The FAS is a six-point, single-item measure of perceived activation. The scale ranges  
2 from 1 to 6, with anchors at 1 (Low Arousal) and 6 (High Arousal). The FAS has exhibited  
3 correlations in the range .45 to .70 with the arousal scale of the Self-assessment Manikin and  
4 .47 to .65 with the arousal scale of the Affect Grid [8]. State motivation (SM) was assessed  
5 using a 10-point state motivation scale [58]. Motivation was defined at the situational level,  
6 which refers to the motivation one experiences while engaging in a particular activity [59].  
7 The scale was anchored by 0 (Not at all motivated) and 10 (Extremely motivated), based on a  
8 “how do you feel right now” response set. Tenenbaum et al. [58] provided a strong rationale  
9 for the applicability of single-item scales where they demonstrate high face validity.

10 **Procedure.** Participants completed a total of eight laboratory sessions: An initial  
11 incremental exercise test, to determine maximal oxygen uptake ( $\text{VO}_2 \text{ max}$ ) ventilatory  
12 threshold, a habituation session, and six subsequent experimental trials. Participants ran at  
13 velocities corresponding to 10% of maximum capacity above and below VT during the  
14 experimental trials. Pilot testing indicated that participants were able to maintain exercise for  
15 the necessary duration at 10% above VT.

16 **Pretest and habituation.** The first test consisted of a modified (ramp protocol)  
17 incremental exercise test [60]. The treadmill test was terminated at the point of volitional  
18 exhaustion and maximal oxygen uptake ( $\text{VO}_2 \text{ max}$ ) was verified using standard criteria [9].  
19 All participants demonstrated at least two of the following three criteria: (a) terminal  
20 respiratory exchange ratio (RER) greater than 1.10; (b) 95% or greater of the age-predicted  
21 maximal heart rate ( $\text{HR} = 220 - \text{age}$ ); and (c) a plateau in  $\text{VO}_2$  with increasing workload. The  
22 highest level of oxygen uptake, averaged over 20 s, was designated as  $\text{VO}_2 \text{ max}$ . VT was  
23 identified using the ventilatory equivalent for  $\text{VO}_2$  method [61, 62]. The speed and grade  
24 corresponding with 10% of maximum capacity above and below VT for each participant  
25 were determined by plotting the treadmill protocol against  $\text{VO}_2$  from each participant’s pre-

1 test data and interpolating the target treadmill speed and grade. A target HR corresponding  
2 with 10% above ( $M = 181.5$ ,  $SD = 8.7$  bpm) and below ( $M = 148.4$ ,  $SD = 7.1$  bpm) VT was  
3 also calculated for each participant from the pre-test data by plotting HR against  $VO_2$ .

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

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

16 Upon arrival at the laboratory, baseline affective valance was collected and each  
17 participant was fitted with a HR monitor. Once the integrity of the HR signal was established,  
18 participants were led through a 5-min dynamic warm-up using a brief series of active  
19 stretches. This was followed by a 3-min walk on the treadmill at 3 mph. Participants were  
20 briefed on the experimental protocol and afforded an opportunity to ask questions. The  
21 treadmill was then set at the predetermined speed (mph) and grade to correspond with either  
22 10% of maximum capacity above or below VT for each individual to commence the test. In-  
23 task measures (state attentional focus, RPE, FS, FAS, and state motivation) were taken just  
24 prior to minutes 5, 10, and 15 min of each condition. Upon completion of each testing bout,  
25 the researcher gradually reduced the velocity of the treadmill belt to 2.0-2.5 mph and the

1 participant completed a 3-min cool-down. Following this, the participant dismounted the  
2 treadmill and sat to complete the posttask measure of affective valence.

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

### 8 **Data Analysis**

9 Data were screened for univariate and multivariate outliers then tested for the  
10 parametric assumptions that underlie mixed-model ANOVA and MANOVA. The attention  
11 and psychophysical variables (state attention and RPE) were assessed using a 3 (Condition) x  
12 2 (Intensity) x 3 (Time) MANOVA, as were in-task affective variables (affective valence and  
13 perceived activation scores). State motivation was assessed using a 3 (Condition) x 2  
14 (Intensity) x 3 (Time) ANOVA. Significant omnibus statistics were followed by F tests that  
15 were Greenhouse-Geisser adjusted where necessary. These were supplemented by  
16 Bonferroni-adjusted pairwise-comparisons.

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

### 23 **Results**

24 Prior to the main analyses, data were checked for univariate outliers, of which there  
25 were two that were suitably adjusted (see [64], pp. 107-111). One case exhibited multiple



1 univariate outliers and was thus removed from the dataset. No multivariate outliers were  
2 identified. Tests of the distributional properties of the data in each cell of the analysis  
3 revealed minor violations of normality in 5 of the 124 cells (all at  $p < .05$ ). Tabachnick and  
4 Fidell [64] suggest that the F test is sufficiently robust to withstand such minor violations of  
5 normality. Collectively, the diagnostic tests indicated that the assumptions underlying mixed-  
6 model ANOVA and MANOVA were satisfactorily met. In the interests of parsimony and  
7 given the complexity of the analyses, only significant omnibus and univariate statistics are  
8 presented herein.

### 9 **Attention and Psychophysical Variables**

10       There was just one significant interaction effect (see Table 1), which was for Intensity  
11 x Time and this applied to both state attention ( $p = .006$ ) and RPE ( $p < .001$ ). In the case of  
12 state attention, there was stability in the scores across time at the below-VT intensity, and a  
13 gradual decline in dissociation/increase in association at the above-VT intensity from minute  
14 5 to minute 15. The RPE results exhibit a similar profile to those for state attention given that  
15 there was relative stability in these scores at the below-VT intensity, and an increase in RPE  
16 at the above-VT intensity (see Figure 1).

17       There were three main effects for the psychophysical and attentional variables that  
18 spanned the independent variables of condition, intensity, and time (see Table 1). For  
19 condition, the RPE scores in the music-and-video condition were significantly ( $p = .008$ )  
20 lower than those in control ( $M_{diff} = .39$ ,  $SD = .52$ ), while the state attention scores revealed  
21 differences among all three conditions (all  $p < .01$ ). The music-and-video condition yielded  
22 the highest level of dissociation ( $M = 75.92$ ,  $SD = 10.55$ ), followed by the music-only  
23 condition ( $M = 67.20$ ,  $SD = 13.09$ ), and control ( $M = 52.86$ ,  $SD = 16.45$ ). For intensity, there  
24 were significantly ( $p < .001$ ) higher RPE scores and a higher degree of association at the

1 above-VT intensity, when compared to below-VT. For time, there was a strong effect evident  
2 for RPE ( $p < .001$ ;  $\eta_p^2 = .71$ ), wherein ratings increased from minute 5 to minute 15.

### 3 **Affective Variables**

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

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

21 **Pre- to posttask.** There was a higher-order (threeway) interaction (see Table 1)  
22 wherein posttask affective valence was significantly higher at the below-VT intensity  
23 following exposure to the experimental conditions when compared to control ( $M_{diff} = .56$ ,  $SD$   
24  $= 1.20$ , and  $M_{diff} = .85$ ,  $SD = 1.19$  for music and music-and-video respectively). However,  
25 this effect was not evident at the above-VT intensity, where there was a large decline in affect

1 followed by a strong rebound in the control condition when compared to the music and  
2 music-and-video conditions (see Figure 2).

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

### 7 **State Motivation**

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

### 15 **Correlations between State Attention and In-task Affective Valence**

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

## 22 **Discussion**

23 The main purpose of this study was to examine the effects of auditory and visual  
24 stimuli on a range of psychological and psychophysical variables (attentional focus, RPE,  
25 affective valence, perceived activation, and state motivation) at intensities below and above

1 the ventilatory threshold during treadmill running. A secondary purpose was to examine the  
2 effects of auditory and visual stimuli on affective valance across the entire exercise session  
3 and to explore the relationship between state attention and in-task affective valance.

#### 4 **Attention and Psychophysical Variables**

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

22 The anticipated Condition x Intensity interaction ( $H_3$ ) did not emerge for either  
23 variable, indicating that the influence of music and music-video on state attention and RPE  
24 during treadmill running does not appear to be moderated by task intensity. This finding is  
25 inconsistent with Tenenbaum's [33] load-dependent theory of effort perception and

1 attentional focus. The theory predicts that at low-to-moderate exercise intensities, an  
2 exerciser's RPE can be moderated by external cues, but this does not hold during high-  
3 intensity exercise. In the present study, the combined stimuli of music and video were  
4 seemingly able to capture participants' attention and reduce their RPE at intensities above  
5 and below VT. This is the first experimental study to date that has tested the combination of  
6 auditory and visual stimuli at running intensities above and below VT. Therefore, it is  
7 possible that this combination of external stimuli might have been sufficiently engaging, from  
8 an information processing perspective, to extend the physiological parameters at which  
9 exercise participants gain meaningful psychophysical and attentional benefits [43]. This  
10 novel finding is consistent with field-based research demonstrating the superiority of  
11 combined entertainment (music and television) when compared to music only, TV only, or  
12 control on measures of exercise duration, cardiorespiratory fitness, and exercise adherence  
13 [42].

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

20         The main effects of intensity and condition for state attention are consistent with  
21 previous research [17, 23, 66] that has demonstrated an “attentional shift” from dissociative  
22 to associative attentional focus with increasing task intensity. In the present study, there was a  
23 strong shift toward association above VT, with a mean difference of 15 units (scale range: 0–  
24 100) between the low and high exercise intensities. The current findings also support Terry  
25 and Karageorghis' [67] conceptual framework regarding the benefits of music in sport and

1 exercise contexts, wherein dissociation from unpleasant feelings is identified as one of the  
2 potential benefits of music listening during exercise.

### 3 **Affective Variables**

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

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

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

13           **State attention and in-task affective valence.** In line with H<sub>4</sub>, state attention scores  
14 were positively correlated with in-task affective valence at both exercise intensities in the  
15 experimental conditions, but not control. This provides evidence for attentional manipulation  
16 as one of the underlying mechanisms by which music and music-and-video might improve  
17 affective valence during exercise [6, 19]. Correlations were stronger at the  
18 above VT intensity ( $r = .55-.59$ ) than below VT ( $r = .40-.49$ ). A plausible explanation for  
19 this is that above VT, the two experimental conditions had a stronger bearing on affective  
20 responses during the exercise bout than they did below VT. Specifically, it appears that these  
21 conditions engendered more positive affect at a workload that, according to the DMT [12], is  
22 associated with greater variability in affective responses. In line with DMT, cognitive cues  
23 are more salient at lower intensities of exercise, but above VT there is a stronger influence  
24 of interoceptive cues that influence the affective centers of the brain (i.e., the amygdala,  
25 anterior cingulate, and insular cortex).

1           **Post-task affective valence.** When baseline and in-task affective valence were  
2 compared to post-task affective valence, there was a predictable post-task improvement and  
3 the experimental conditions were associated with more positive affect than the control; thus  
4 H<sub>5</sub> was supported. The significant Condition x Intensity x Time interaction effect (see Table  
5 1) demonstrates that post-task affective valence can be influenced by the in-task affective  
6 experience, and that affective valence following exercise under control conditions does not  
7 rebound to the same level as that for music-and-video [8]. Thus, the choice of attentional  
8 stimuli during exercise may have important implications for post-exercise experience. This,  
9 in turn, may influence the decision to engage in future exercise bouts [11, 38, 39] and go  
10 some way toward addressing the pervasive “revolving door” phenomenon [4].

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

## 21 **State Motivation**

22           A main effect of condition for state motivation showed higher motivation in the  
23 experimental conditions compared to control; accordingly H<sub>1</sub> was supported. There was,  
24 however, no difference between music-only and control, and no Condition x Intensity  
25 interaction; thus H<sub>2</sub> and H<sub>3</sub> were not supported. The significant Condition x Intensity x Time



1 interaction hints at the possibility that the participants, who were habitually active, were not  
2 sufficiently physically challenged by the below-VT intensity, and thus derived some  
3 motivational benefit during the progression of both experimental conditions (see Figure 1). In  
4 comparing exercise intensities in the control condition, participants appeared more motivated  
5 by the challenge imposed by the above-VT intensity. This finding can be interpreted with  
6 reference to flow theory [70], which posits that when the challenge in a situation is low and  
7 the skills of the performer are high, boredom and apathy can ensue.

### 8 **Limitations and Future Directions**

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

21         The present sample was comprised of physically active young adults and thus the  
22 findings cannot be readily generalized to the wider population without replication using a  
23 participant demographic profile that is more broadly representative. The relationship between  
24 acute affective responses to exercise and longer-term adherence among previously sedentary  
25 individuals has received some recent empirical support [11, 38]. The manipulation of affect

1 during exercise with stimuli such as music and video, particularly with “at risk” populations,  
2 is likely to be a fruitful scientific endeavor. It would also be worthwhile to assess whether the  
3 present findings can be applied at a group level through the use of a music-video intervention  
4 in a group exercise context (e.g., a cardiac rehabilitation class). The present participants ran  
5 in a laboratory in relative isolation and it is noteworthy that in most real-life exercise  
6 environments, there would be other exercisers present, with the potential to offer additional  
7 distraction or social support.

8 In the present study, participants ran at workloads corresponding with 10% below and  
9 10% above VT. This facilitated a physiologically meaningful distinction between conditions  
10 and was representative of exercise intensities that have applicability in the field. In addition,  
11 the selection of the 10% below and 10% above VT enabled a stringent test of the hypotheses  
12 that emanate from Ekkekakis’ (2003) dual-mode theory, given that if the experimental stimuli  
13 were found to be effectual at 10% above VT, they would also be effectual at VT. It would  
14 have been illuminating to also consider exercise at VT, however the 11 laboratory visits  
15 required from participants to achieve this would have constituted an undue demand.

16 The aesthetic congruence of the music and video used in the combined-stimuli  
17 condition cannot always be replicated in health and fitness facilities; oftentimes people listen  
18 to their own music but are compelled to watch screens that project material that is entirely  
19 unrelated (e.g., news channels). Thus there is a need for studies to examine the efficacy of  
20 incongruent audio and visual stimuli in such settings. A further useful addition to this line of  
21 research would be to explore which types of video material are most effective. Such work  
22 might also be meaningfully extended in order to examine the degree of immersion that is  
23 required to optimize the effects of audiovisual stimuli during exercise. Can the positive  
24 findings reported herein be replicated using a smaller television screen that is more typical of  
25 health and fitness facilities? Might the findings be enhanced through use of a more immersive

1 environment (e.g., using over-ear headphones vs. speakers)? A recent trend has been toward  
2 the use of instructor-led exercise programs that are delivered via smartphones and tablets  
3 (e.g., Fitness Buddy). There is the potential here to combine music interspersed with vocal  
4 encouragement, and video, in order to encourage the user to exercise at a place and time  
5 convenient to them. This approach would go some way toward addressing some of the  
6 common “consumer resistances” to structured exercise [5].

### 7 **Conclusions**

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

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1 Table 1  
 2 Significant Inferential Statistics for all Dependent Variables

	Multivariate Results				
	Pillai's	F	Df	p	$\eta_p^2$
<b>Psychophysical and Attention Variables</b>					
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
<b>Affective Variables</b>					
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	$\eta_p^2$	
<b>State Attentional Focus</b>					
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	
<b>Ratings of Perceived Exertion</b>					
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	
<b>Affective Valance</b>					
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	
<b>Perceived Activation</b>					
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	
<b>Affective Valance (baseline, during, posttask)</b>					
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	
<b>State Motivation</b>					
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	

1  
2

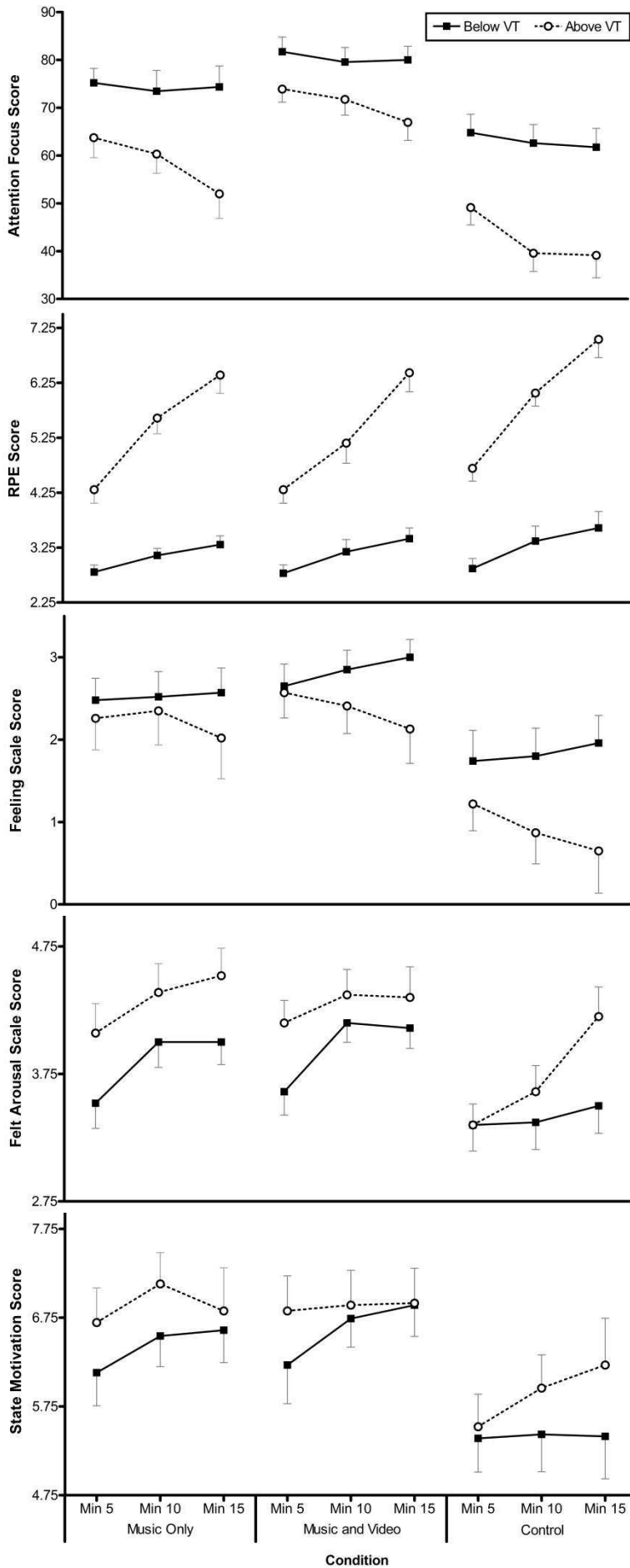
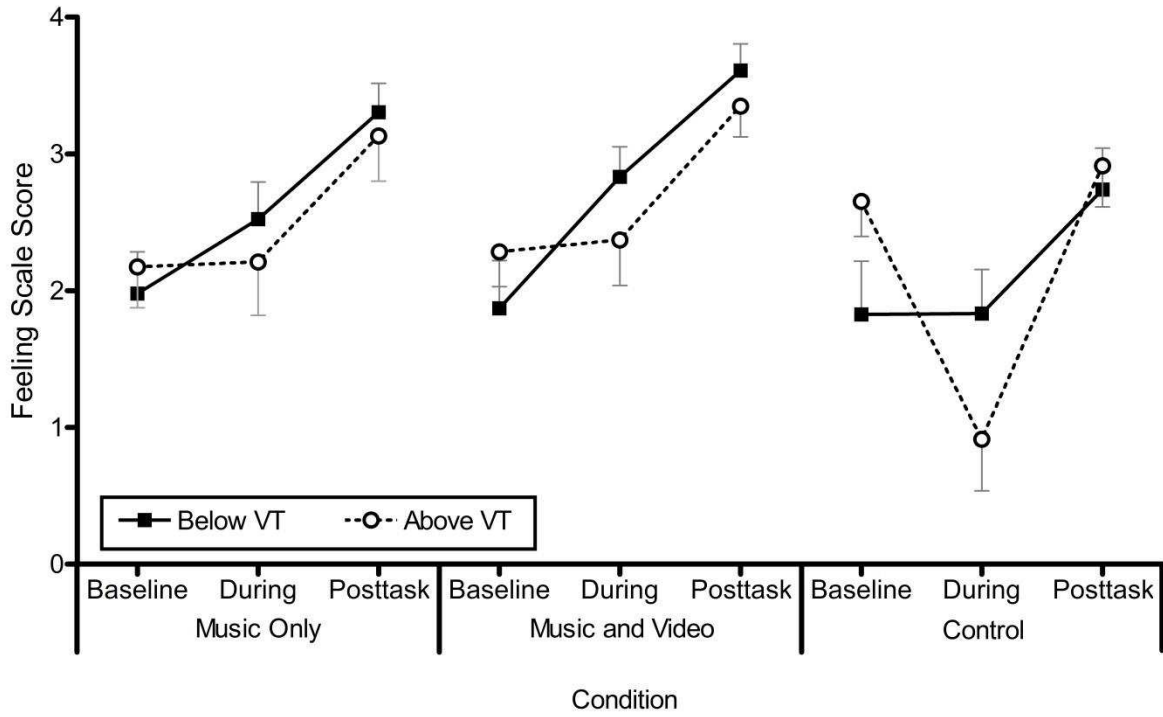


Figure 1. Condition x Intensity x Time interaction for all dependent variables.



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

2