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

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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 Jones²

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

²School of Sport and Education, Brunel University, UK

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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_1). 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_2). 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_3).

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 (VO_2 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 (VO_2 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 VO_2 with increasing workload. The
22 highest level of oxygen uptake, averaged over 20 s, was designated as VO_2 max. VT was
23 identified using the ventilatory equivalent for 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 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 (± 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 ($M_{\text{diff}} = .39$, $SD = .52$), 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 ($p < .001$; $M_{\text{diff}} = 1.07$, $SD = .48$). A main effect of condition showed that both
 5 experimental conditions were associated with greater positive affect than control ($p < .001$;
 6 $M_{\text{diff}} = .72$, $SD = .48$, and $M_{\text{diff}} = .95$, $SD = .91$ 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_4 , 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_5 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_1 was supported. There was,
24 however, no difference between music-only and control, and no Condition x Intensity
25 interaction; thus H_2 and H_3 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	<i>F</i>	<i>Df</i>	<i>p</i>	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				
	<i>F</i>	<i>Df</i>	<i>p</i>	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	

1
2

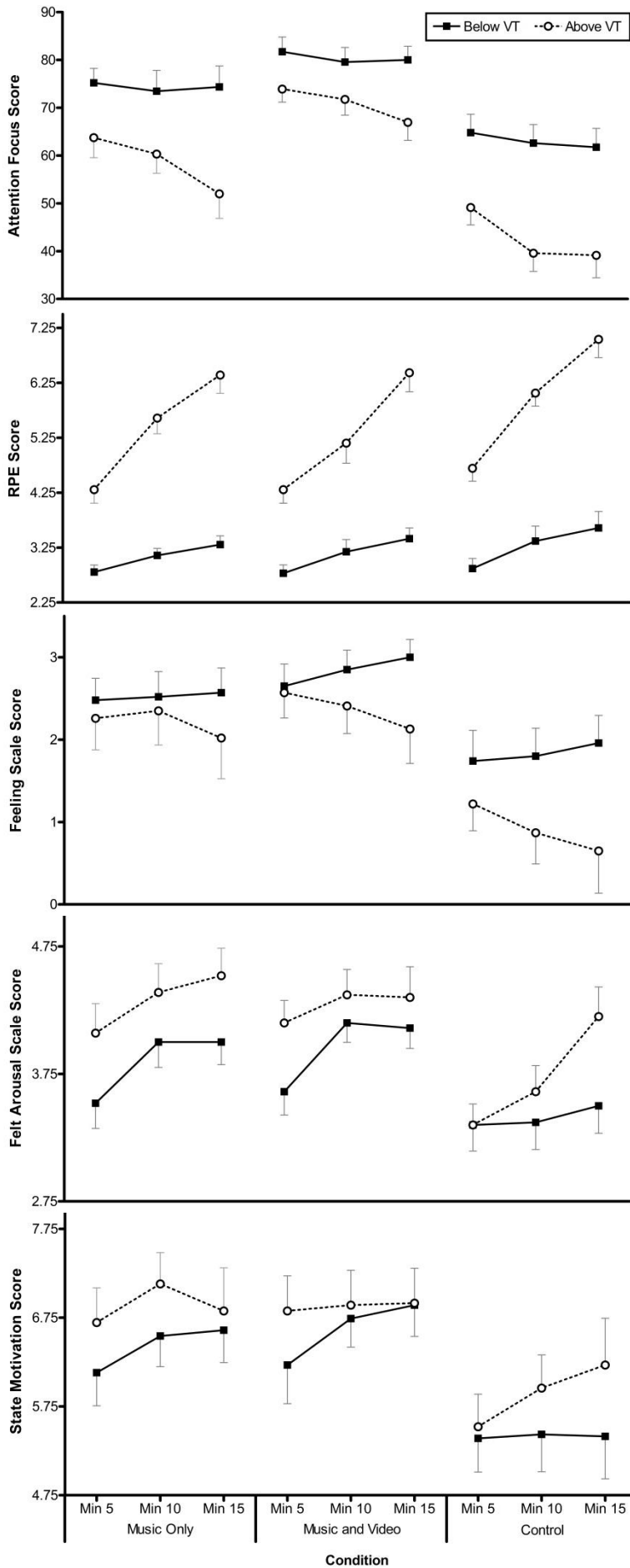
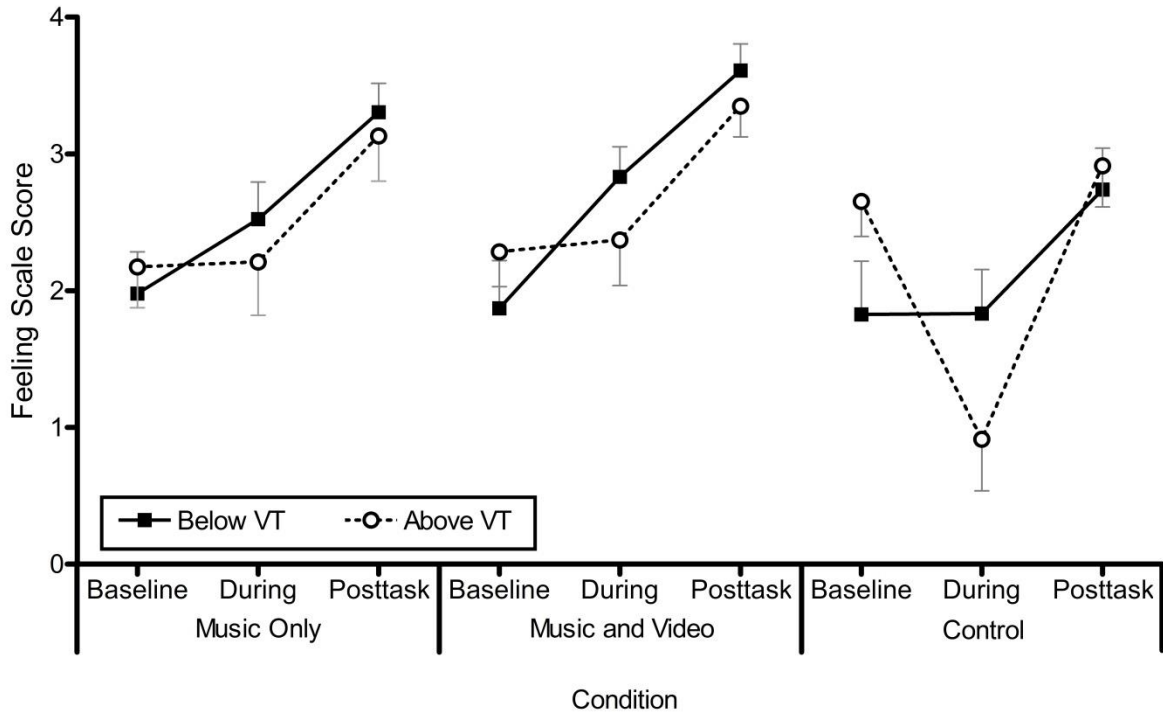


Figure 1. Condition x Intensity x Time interaction for all dependent variables.



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

2