Running Head: EFFECTS OF MUSIC, VIDEO, AND 360-DEGREE VIDEO

Effects of Music, Video, and 360-Degree Video on Cycle Ergometer Exercise at the Ventilatory Threshold

Jonathan M. Bird[1], Costas I. Karageorghis[1], Steven Baker[2], and David Brookes[2]

1 Brunel University London, UK

2 University of Gloucestershire, UK

Second resubmission: March 22, 2019

Author Note

Jonathan M. Bird, Department of Life Sciences, Brunel University London; Costas I. Karageorghis, Department of Life Sciences, Brunel University London, Steven Baker, Department of Psychology, University of Gloucestershire; David Brookes, Department of Psychology, University of Gloucestershire.

Correspondence concerning this article should be addressed to Costas I. Karageorghis, Department of Life Sciences, Brunel University London, United Kingdom, UB8 3PH.

Email: costas.karageorghis@brunel.ac.uk

Tel: +44 (0)1895 266476

Abstract

Despite the seemingly ubiquitous presence of audiovisual stimuli in modern exercise facilities, there is a dearth of research examining the effects of audiovisual stimuli in combination during exercise. Accordingly, we examined the influence of a range of audiovisual stimuli on the improvement of affective, perceptual, and enjoyment responses to cycle ergometer exercise at the ventilatory threshold (VT); an intensity that is associated with the most affect-related interindividual variability. A within-subjects design was employed and participants (*N* = 18) completed a 25-min protocol that consisted of 2 min of seated rest, 5 min warm-up, 10 min exercise at VT, 5 min cooldown, and 3 min of seated rest. Participants exercised at VT under music, video, music-video, 360-degree video, 360-degree video with music, and control conditions. The results revealed a condition × time interaction for perceived activation and a main effect of condition for state attention and perceived enjoyment. The 360-degree video with music condition elicited the most positive affective valence, greatest perceived activation, most dissociative thoughts, and highest ratings of perceived enjoyment. The present findings indicate that audiovisual stimuli can influence affective, perceptual, and enjoyment responses to cycle ergometer exercise at the VT. Given the emerging support pertaining to a positive relationship between affective responses and exercise adherence, audiovisual stimuli, such as 360-degree video with music, should be considered as a means by which to promote an enjoyable exercise experience.

Keywords: dual-process models; exercise psychology; head-mounted display; immersion; physical activity; virtual reality

Physical (In)Activity

Engagement in physical activity is fundamental to the prevention of numerous chronic diseases, such as heart disease, type 2 diabetes, and some cancers.[1] The benefits of physical activity are so widely documented that the World Health Organization's Global Action Plan for the Prevention and Control of Non-Communicable Diseases includes the target to reduce physical inactivity by 10% by 2025.[2] Unfortunately, progress toward this goal appears to be significantly off track.[3] Researchers using self-report data estimate that 23.3% of the adult population fails to achieve 150 min of moderate intensity activity or 75 min of vigorous intensity activity per week.[4] However, the severity of physical inactivity is often underestimated when predicated on self-report data when compared to objective assessments using accelerometer data.[5] Hence, there is a strong need for interventions that aim to enhance physical activity among the general population.

For the past 50 years, the dominant metatheoretical perspective within exercise psychology has been the cognitive paradigm. Theories based on this paradigm adhere to the rational-educational model wherein individuals are viewed as rational thinkers who collect, interpret, and reliably act upon information that serves their greatest self-interest.[6] Any instances of irrational behavior are proposed to be corrected by supplying the individual with more accurate information concerning the consequences of her/his behavior.[5] However, it appears that individuals *understand* the benefits associated with physical activity that are emphasized by public health campaigns and yet still choose to refrain from engagement in physical activity. Therefore, the field of exercise psychology faces a "paradigmatic crisis" wherein current theoretical models are misaligned with available data.[6]

Dual-Process Models

Researchers are beginning to conceptualize physical activity and exercise behavior using dual-process models. It is acknowledged that individuals often behave in ways that do not serve their self-interests.[5] Dual-process models hold that behavioral decision making is founded upon two main processes. Type 2 processes reflect those that are postulated by current cognitive theories; they are slow, reflective, and require deliberate contemplation of available information. On the other hand, Type 1 processes are primitive, automatic, and intuitive. Such processes are governed by heuristics, which are simplified rules that allow individuals to make decisions quickly (ie, bounded-rationality).[7]

The *affect heuristic* has been proposed to be an essential component of physical activity behavior.[6] Based on the hedonic principle,[8] the affect heuristic reflects the notion that individuals are likely to gravitate toward behaviors that result in pleasure and avoid those behaviors that result in pain.[9] Physical activity holds a precarious position that has the potential to cause conflict between Type 1 and Type 2 processes.[6] Individuals are aware of the numerous health benefits associated with physical activity (via Type 2 processes). Nonetheless, many individuals' affective reactions at the time of decision making contain a negative hedonic tone (via Type 1 processes), owing to a history of experienced discomfort associated with physical activity (eg, muscle acidosis, labored breathing). The automaticity of Type 1 processes has the capacity to override the more rational decision-making process that underlies Type 2 processes. This ultimately results in individuals refraining from engagement in physical activity. A related but distinct concept of central importance concerns perceived enjoyment, which is typically measured postexercise by means of multi-item questionnaires and has been found to be associated with future physical activity behaviors.[10,11]

Dual-Mode Theory of Affective Responses to Exercise

Affect is defined as "a neurophysiological state consciously accessible as a simple primitive nonreflective feeling most evident in mood and emotion but always available to consciousness."[12(p104)] We conceptualize affect as a dimensional domain, comprised of two orthogonal and bipolar dimensions, affective valence (ranging from pleasure to displeasure) and perceived activation (commonly referred to as "arousal"). Researchers have drawn upon the intensity of exercise to help explain the variance observed in affective responses across individuals. An underlying premise of the dual-mode theory[13] is that exercise intensity should be defined in accord with fixed metabolic markers such as the ventilatory threshold (VT) and respiratory compensation point (RCP), both of which are associated with several physiological changes (eg, increased respiration rate and carbon dioxide production).

According to the theory, affective responses below VT (ie, low-to-moderate intensities) are primarily driven by cognitive factors and are largely pleasurable. Affective responses to exercise proximal to VT (ie, heavy intensities) are associated with the most interindividual variability, with some individuals experiencing an increase in pleasure and others a decrease in pleasure. At intensities beyond the RCP (ie, severe intensities), interoceptive cues gain salience and there is a near universal decline in pleasure, as a physiological steady state becomes impossible to maintain.[13] Moreover, upon cessation of strenuous exercise that induces a decrease in pleasure, a rapid rebound toward pleasure is expected to occur.[14] Given the dynamic nature of affective responses to exercise, it is advised that such responses are recorded throughout the entire exercise bout (ie, pre-, during, and post-exercise).[14] Such an approach ensures that the most influential affective elements of exercise are captured (ie, the *peak affect*, the *end affect* and, the slope of affective change during the bout).[15] Focusing on affective constructs when designing interventions to promote physical activity may hold promise,[16] although it has been suggested that there is a paucity of information regarding how we can achieve this in practice.[17]

Enhancing Affective Responses to Exercise with Audiovisual Stimuli

One possible strategy for enhancing affective responses concerns the addition of audiovisual stimuli within the exercise environment. A substantial body of research has demonstrated that music can facilitate positive affective responses to exercise and physical activity across several modalities including cycle ergometry,[18] treadmill running,[19] and self-paced walking.[20] A mechanism proposed to underlie these findings concerns *attentional dissociation,* which refers to the way in which music can divert attention away from the unpleasant somatic sensations associated with strenuous exercise.[21]

Building upon the theoretical premise that greater attentional dissociation might yield more positive affective responses to exercise, investigators have examined the influence of audio and visual stimuli in combination. This represents an ecologically valid form of scientific inquiry, as audiovisual stimuli have become almost ubiquitous within modern-day exercise facilities. A range of stimuli have been employed by researchers including music-videos,[22] movie footage,[23] sporting highlights,[24] and even circus performances.[25] A novel approach was adopted by Jones, Karageorghis, and Ekkekakis,[26] who used rural parkland-based video footage filmed from a cyclist's point of view. The researchers found that music-only and music-video conditions could yield more positive affective responses to exercise at intensities 10% below and 5% above VT compared to video-only and control conditions. Jones et al.[26] created an immersive environment by projecting video footage onto a large screen placed in front of participants. The researchers concluded that a fruitful direction for future research concerns the degree of immersion required to optimize the effects of audiovisual stimuli on exercise-related affect.

Immersion and Presence

The term *immersion* refers to the technical capabilities of a system to afford the individual to perceive through natural sensorimotor contingencies.[27] That is, to be able to perceive the stimuli in a natural way. Hence, it is possible to place systems on a continuum according to the degree of immersion that they confer. One type of system that has the potential to engender higher degrees of immersion when compared to video projection[26] is a virtual reality head-mounted display (VR HMD). This has the capacity to subject individuals to a range of audiovisual content (eg, 360-degree videos, virtual environments). VR HMDs are considered immersive because they occlude the individual from physical reality (ie, are inclusive), accommodate a range of senses (ie, are extensive), offer panoramic environments (ie, surround the participant), and comprise high-resolution displays (ie, are vivid).[28,29] A correlate of immersion is *presence*, which refers to the sense of being in the virtual environment, despite the fact that you know that you are not actually there.[27,30]

Virtual Reality Empirical Research

Researchers from the realm of medicine have employed VR technology to assist in the treatment of chronic and procedural pain for some time. For example, Schmitt et al.[31] examined the effectiveness of a virtual environment depicting a wintery scene on burn outpatients' pain ratings. Participants reported significant reductions in pain of 27-44% and elevated levels of "fun" when undertaking physical therapy with VR accompaniment. Using a randomized controlled trial, Gold and Mahrer[32] found that VR could significantly reduce procedural pain and anxiety associated with blood draw in children when compared to the standard of care. Moreover, Tashjian et al.[33] reported that a VR experience could significantly reduce inpatients' pain ratings when compared to a 2D video control condition.

The findings above indicate that VR represents a useful technology to distract individuals from the sensation of pain. A related but distinct sensation pertains to exercise-related discomfort, which is expected to occur at most exercise intensities. Accordingly, it is plausible that the aforementioned findings could translate to an exercise context. Nonetheless, research employing VR in an exercise context is scant. A study by Zeng, Pope, and Gao[34] provides a notable exception: They investigated the physiological and psychological effects of exercising on a VR-enabled cycle ergometer compared to a traditional cycle ergometer. The results indicated that higher self-efficacy and enjoyment scores were reported in the VR condition when compared to the traditional cycle ergometer condition. Participants also reported significantly lower ratings of perceived exertion (RPE) in the VR condition, indicating that VR-mediated exercise might offer a useful means of encouraging attentional dissociation.

There were, however, some notable limitations evident in the Zeng et al.[34] study. Foremost among these, the researchers employed one exercise intensity in the VR condition, as opposed to defining intensity according to a fixed metabolic marker, such as VT.[13] In addition, participants were able to listen to music or watch videos during the traditional cycle ergometer condition, although the precise nature of these stimuli was not delineated. Hence, there appears to be considerable scope to examine the effects of audiovisual stimuli delivered via VR HMDs during exercise while accounting for the aforementioned limitations.

Aims and Hypotheses

The present study was predicated on the notion that a dissociative manipulation of attentional focus through the application of music, video, music-video, 360-degree video, and 360-degree video with music would be reflected in participants' subjective ratings of affect (ie, affective valence and perceived activation), attentional focus, RPE, and perceived enjoyment. Accordingly, our aim was to examine the influence of a range of audiovisual stimuli on affective and perceptual responses to exercise at the VT; an intensity that is associated with the most affect-related interindividual variability.[14]

It was hypothesized that conditions containing 360-degree video would facilitate the most positive affective valence and highest perceived activation. Moreover, we expected that music-video, music, and video conditions would elicit more positive affective valence and higher perceived activation when compared to the control condition (H_1). Furthermore, we predicted that the control condition would prompt the greatest "affective rebound", owing to participants' less positive in-task affective state (H_2). We expected conditions containing 360-degree video to elicit the most dissociative thoughts and lowest RPE. In addition, we hypothesized that music-video, music, and video conditions would prompt more dissociative thoughts and lower RPE when compared to the control condition (H_3). Finally, we expected conditions containing 360-degree video to facilitate the greatest perceived enjoyment. It was also predicted that music-video, music, and video conditions would prompt greater perceived enjoyment when compared to control (H_4).

Methods

This study was approved by the first and second authors' institutional ethics committee and participants provided written informed consent. Personal factors are proposed to influence an individual's response to a piece of music.[35] Accordingly, participants were homogenous in terms of age (ie, 18-31 years), ethnicity (ie, White British), and sociocultural background (ie, formative years spent in the UK) at each stage of the present study. None of the participants reported any form of hearing deficiency and/or visual impairment.

Music Selection

A sample of 42 University of Gloucestershire and Brunel University London students (M_{age} = 21.6 ± 1.9 years) were used to identify possible music selections that could be administered during the experimental phase of the study. Given that responses to music during exercise are influenced by situational factors (eg, exercise/training location, mode/intensity of exercise),[35] participants were instructed to specify up to five pieces of music that they considered motivational for high-intensity, indoor cycling (ie, the intensity and exercise modality for the experimental phase). A total of 181 tracks were ranked by tempo and 15 tracks that were at an appropriate tempo for high-intensity indoor cycling (ie, 135-145 bpm)[35] were subjected to further testing.

A purposively selected sample of 10 exercise science majors at the University of Gloucestershire (M_{age} = 19.1 ± 0.6 years) rated the motivational qualities of each track using the Brunel Music Rating Inventory-3.[35] Participants were instructed to rate the music with reference to high-intensity, indoor cycling. The rating procedure ensured that the tracks used during the experimental phase were homogenous in terms of their motivational qualities.[36] The final track selection was aided by the qualitative guidelines of Karageorghis et al.[36] and three tracks with similar motivational qualities were chosen for use during the experimental phase (Table S1). GarageBand (Apple Inc., California) software was used to segue the selections into a coherent playlist that lasted for 10 min.

Video Selection

We employed video footage that depicted the exercise modality under investigation (ie, cycle ergometry). The first author perused *YouTube* to source monoscopic 360-degree videos. Specifically, the author searched for "Cycling 360" and filtered the search results by (a) Video Duration – Long (> 20 min) and (b) Features – 4K Resolution and 360-degree. Subsequently, he viewed 15 videos and selected one according to (a) recording factors (eg, camera stability) and (b) the footage characteristics (eg, minimal changes in elevation and cornering, traffic-free roads). The author showed the selected video to the aforementioned sample of 10 exercise science majors at the University of Gloucestershire ($M_{age} = 19.1 \pm 0.6$ years) and asked them to indicate the extent of their agreement that the video was appropriate for high-intensity indoor cycling by use of a 5-point scale anchored by 1 (*strongly disagree*) and 5 (*strongly agree*).[26] Nine of the ten respondents indicated that they agreed or strongly agreed that the video was appropriate for high-intensity indoor cycling.

Experimental Investigation

Power Analysis

A power analysis was conducted using the software G*Power 3 to establish a suitable sample size for a repeated-measures (RM), within-subjects MANOVA.[37] This analysis was predicated on a large effect size for a condition × time interaction for affective valence reported by Hutchinson, Karageorghis, and Jones ($\eta_p^2 = .30$)[38] and indicated that 18 participants would be required ($\alpha = .05$; $1 - \beta = .80$).[39]

Participants

A convenience sample of 18 adult volunteers was recruited for the experimental phase of the study (9 women and 9 men; $M_{age} = 24.17 \pm 4.23$ years; $M_{BMI} = 22.98 \pm 3.05$ kg m^{-2}; M $\dot{V}O_{2peak} = 37.07 \pm 6.36$ ml kg^{-1} min^{-1}). Recruitment was conducted through word-of-mouth and aided by means of promotional posters at the University of Gloucestershire. Participants were deemed eligible to engage in exercise, according to the Physical Activity Readiness Questionnaire (PAR-Q).[40] Participants were familiar with cycle ergometry, the selected exercise modality for the present study.

Apparatus and Measures

An electronically-braked cycle ergometer (Lode Excalibur Sport; Groningen, Netherlands) was used for the pretest and during all experimental trials. In addition, a VR HMD (Samsung Gear VR; Suwon, the Republic of Korea), smartphone (Samsung S8; Suwon, the Republic of Korea), laptop (Apple MacBook Pro; Apple Inc., California), and wireless headphones (AfterShokz Trekz Titanium; Cheshire, United Kingdom) were used during the experimental trials to deliver the audiovisual stimuli. Music intensity was standardized at ~70 dBA.

On the basis that we conceptualize affect as a dimensional domain, affective valence was assessed using the Feeling Scale (FS)[41] and perceived activation was measured using the Felt Arousal Scale (FAS).[42] The FS is a single-item, 11-point scale anchored by -5 ([*I feel*] *very bad*) and 5 (*very good*). The FAS is a single-item, six-point scale anchored by 1 (*low arousal*) and 6 (*high arousal*). RPE was assessed using the Borg CR10 Scale,[43] which is anchored by 0 (*nothing at all*) and 10 (*extremely strong*). Attentional focus was measured using Tammen's Attention Scale,[44] which is anchored by 0 (*Internal focus* [*bodily sensations,* *heart rate, breathing, etc.*] and 100 (*External focus* [*daydreaming, external environment, etc.*]. Perceived enjoyment was assessed postexercise using the Physical Activity Enjoyment Scale (PACES).[45] This scale includes 18 items attached to 7-point bipolar scales (eg, 1 = *I enjoy it,* 7 = *I hate it* [item 1]).

Pretest and Habituation

During this session, the particulars of the study were discussed, anthropometric data were collected, participants were habituated to the VR HMD, and peak aerobic capacity and ventilatory threshold were determined. After each participant had confirmed their eligibility for the study and provided written informed consent, the first author measured their height, weight, and resting heart rate. Each participant was then introduced to the measures that were to be administered during the experimental trials. Thereafter, the participant was granted an opportunity to habituate her-/himself with the VR HMD. After becoming comfortable wearing and adjusting the device, the participant was instructed to complete the experience *Introduction to Virtual Reality* (Oculus, California), which is designed to gradually acquaint users with the key concepts of VR.

The participant was then required to remove the VR HMD in order to complete a maximal exercise test on the cycle ergometer. For this purpose, s/he was fitted with a mouthpiece that was connected to a metabolic cart (Ultima Series CardiO_2, MGC Diagnostics, Minnesota). The flow sensor and gas were calibrated prior to each maximal exercise test in order to facilitate accurate measurement of oxygen consumption and carbon dioxide production. After a 2-min warm-up (0 W), the workload was increased to 60 W and thereafter, increased by 25 W per min in a ramp fashion. Upon reaching volitional exhaustion, the mouthpiece was removed from the participant and s/he completed a 5-min cooldown (0 W). VT was later determined by the researcher by use of the V-slope protocol.[46] This entailed plotting $\dot{V}CO_2$ by $\dot{V}O_2$ data in Microsoft Excel and dividing it into two segments, each of which were fitted with a linear regression. The location of the intersection between the two regression lines was then calculated. Thereafter, the researcher identified the pair of regression lines that maximized the ratio of the distance of the intersection point from a single regression line of the data to the mean square error of regression. The solution was accepted as VT if the change in slope from the lower to the upper segment was > 0.1.[46]

Experimental Trials

A within-subjects design was adopted, and experimental testing took place at least 48 hours after the pre-test. There were five experimental conditions (music, video, music-video, 360-degree video, and 360-degree video with music) and one control condition (no music and/or video). In the music condition, participants were exposed to the 10-min playlist while in a visually sterile environment. In the video condition, participants were exposed to the cycling video by means of an Internet browser on a laptop that inhibited the function to navigate the scene in 360-degrees. In the music and video condition, participants viewed the cycling video on a laptop and listened to the 10-min music playlist via headphones. In the 360-degree video condition, participants were administered the cycling video using a smartphone-powered VR HMD. The 360-degree video with music condition entailed viewing the cycling video through the VR HMD while being exposed to the 10-min music playlist. In the control condition, participants were not exposed to music or video footage. Moreover, the participant's eyes and ears were not occluded in order to maintain ecological validity.[26]

Participants were required wear a heart rate monitor during each testing session and participation in each condition lasted a total of 25 min. The FS and FAS were administered following a 2-min period of seated rest (ie, 0-2 min) and subsequently used as baseline values for core affect. Thereafter, participants were required to maintain a cadence of 75 ± 3 rpm on the cycle ergometer, commencing with a 5-min warm-up (0 W; ie, 2-7 min). The appropriate resistance was then applied to correspond with each participant's VT. The exercise bout lasted for 10 min (ie, 7-17 min) and the first author administered the FS, FAS, Attention Scale, and Borg CR10 Scale after 10, 13, and 16 min of each condition.

Once the participant had completed the exercise bout, the researcher lowered the wattage of the cycle ergometer to zero and the participant completed a 5-min cooldown (ie, 17-22 min) before dismounting. The FS and FAS were administered postexercise after 19, 22, and 25 min of each condition, during which time participants were required to remain in a seated position. Moreover, perceived enjoyment was assessed using the PACES upon completion of the cooldown. Participants completed two conditions separated by a rest period upon each visit to the laboratory (Figure S1). Before commencing the second condition, the participant's HR was required to descend to within 10% of her/his resting value. The order of conditions was randomized to limit learning and order effects. However, it was not possible to fully counterbalance the design, owing to the number of conditions that were included (720 participants would have been required). Each participant visited the laboratory on four occasions (one pretest/habituation session and three testing sessions). The experimental trials were scheduled at the same time of day for each participant over a 4-week period, with a minimum of 72 hours between trials.

Data Analysis

Data were screened for univariate outliers through use of standardized *z*-scores (ie, $z > \pm 3.29$)[47] and multivariate outliers using the Mahalanobis's distance test with $P < .001$. Moreover, data were examined for the parametric assumptions that underlie ANOVA and MANOVA.[47] Where variables were theoretically linked, we applied MANOVA to reduce the influence of experimentwise error. Affective variables (affective valence and perceived activation) were assessed using a 6 (condition) × 7 (time) MANOVA. Perceptual variables (RPE and attentional focus) were assessed using a 6 (condition) × 3 (time) MANOVA. Perceived enjoyment was assessed using a oneway, RM ANOVA. We also assessed whether scores on the affective variables and perceived enjoyment varied as a consequence of exercise trial number. This was achieved through calculating the mean of each variable, regardless of condition (Table S2), and running a RM MANOVA for the affective variables, and RM ANOVA for perceived enjoyment.

Greenhouse-Geisser adjustments were made to *F* tests in instances where the sphericity assumption was violated. Where the *F* ratio was significant, Bonferroni-adjusted pairwise comparisons or checks of standard errors were employed to determine where differences lay.[48] Effect sizes were calculated using partial eta squared (η_p^2). Significance was accepted at $P < .05$ for all analyses and exact *P*-values are reported unless $P < .001$.

Results

Prior to the main analyses, univariate outlier tests revealed three outliers ($z > \pm 3.29$) and in all instances, the score was adjusted by assigning the outlying cases a raw score on the offending variable that was one unit larger (or smaller) than the next most extreme score in the distribution until $z < \pm 3.29$.[47] No multivariate outliers were identified. Tests of the distributional properties of the data in each cell of the analysis revealed violations of normality in 41 of the 126 cells (14 at $P < .05$, 11 at $P < .01$, and 16 at $P < .001$). Further testing revealed that 39 of the aforementioned violations of normality were associated with the affective variables (ie, affective valence and perceived activation). However, the *F* test is sufficiently robust to withstand such violation.[47] Moreover, concern has been expressed regarding transformation of subjective data derived from Likert scales.[49] Accordingly, we decided not to transform these data and the results pertaining to the affective variables should be interpreted with these violations in mind. Tests of affective variables and perceived enjoyment across exercise trials indicated that there was only a difference between trial 1 and trial 5 for perceived activation ($P = .020$, 95% CI [0.05, 0.86]; Table S2).

Affective Variables

The omnibus analysis revealed a significant condition × time interaction that applied only to perceived activation (*P* = .019, η_p^2 = .12; Table 1 and Figure 1a) and was associated with a moderate-to-large effect size. Conditions that contained 360-degree video (ie, 360-degree video and 360-degree video with music) elicited significantly higher perceived activation during the exercise bout (ie, after 10, 13, and 16 min) when compared to the control condition. Moreover, all experimental conditions elicited higher perceived activation after 13 min when compared to control. These effects did not continue beyond the exercise bout, as no significant differences were found across conditions during the cooldown and post-task phases (Figure 1a).

There was a main effect of condition that applied only to perceived activation (*P* = .003, η_p^2 = .19; Table 1) and was associated with a large effect size. Pairwise comparisons indicated that perceived activation was significantly higher for 360-degree video with music when compared to control (*P* = .011, 95% CI [0.07, 0.78], *d* = 0.68) and music conditions (*P* = .048, 95% CI [0.01, 0.62], *d* = 0.54). There was a main effect of time for both affective valence (*P* < .001, η_p^2 = .61) and perceived activation (*P* < .001, η_p^2 = .82), both associated with a large effect size. Affective valence scores decreased incrementally throughout the exercise bout and then increased immediately following cessation of exercise. Pairwise comparisons revealed that affective valence was significantly higher during the cooldown (ie, after 19 min) compared to the end of the exercise bout (*P* = .002, 95% CI [0.26, 1.51], *d* = 0.94). Moreover, affective valence scores were significantly higher following a 3-min period of seated rest postexercise (ie, after 25 min) compared to the end of the cooldown (*P* = .045, 95% CI [0.00, 0.57], *d* = 0.41). Perceived activation scores increased incrementally throughout the exercise bout and subsequently decreased postexercise. Pairwise comparisons indicated that perceived activation was significantly higher during the start of the exercise bout (ie, after 10 min) when compared to baseline ($P < .001$, 95% CI [0.77, 1.43], $d = 2.05$). Moreover, perceived activation was significantly lower during the cooldown when compared to the end of the exercise bout ($P < .001$, 95% CI [-1.56, -0.68], $d = 1.91$).

***** Insert Figure 1 about here*****

Perceptual Variables

The omnibus analysis indicated that the condition × time interaction was nonsignificant ($P = .787$, $\eta_p^2 = .04$; Table 1). Nonetheless, there was a main effect of condition that applied only to state attention ($P < .001$, $\eta_p^2 = .31$) and was associated with a large effect size. Pairwise comparisons showed that 360-degree video and 360-degree video with music elicited significantly greater external focus when compared to control ($P = .041$, 95% CI [0.42, 31.80], $d = 0.78$ and $P = 0.10$, 95% CI [3.72, 38.94], $d = 1.03$, respectively; Figure 2). Moreover, 360-degree video with music prompted a significantly greater external focus when compared to the video-only condition ($P = .015$, 95% CI [2.32, 30.54], $d = 0.82$). There was a main effect of time for perceived exertion only ($P = .004$, $\eta_p^2 = .36$) that was associated with a large effect size. Participants reported incrementally greater perceived exertion throughout the exercise bout. Pairwise comparisons revealed that perceived exertion was significantly higher after 13 min and 16 min when compared to 10 min ($P = .003$, 95% CI [0.14, 0.74], $d = 0.49$ and $P = .019$, 95% CI [0.80, 1.01], $d = 0.57$, respectively).

***** Insert Figure 2 about here*****

Perceived Enjoyment

A oneway, RM ANOVA revealed a significant effect of condition ($P = .011$, $\eta_p^2 = .20$; Table 1) that was associated with a large effect size. Pairwise comparisons indicated that the music-video condition elicited significantly greater enjoyment when compared to control ($P = .008$, 95% CI [2.56, 23.67], $d = 0.78$; Figure 3). The difference between the 360-degree video with music condition and the control condition did not reach significance ($P = .150$, 95% CI [-2.34, 28.78]), although the difference between means was in the expected direction ($M_{control}$ = 84.67; $M_{360degreevideowithmusic}$ = 97.89; d = 0.72; Figure 3).

***** Insert Figure 3 and Table 1 about here*****

Discussion

The main purpose of this study was to investigate how participants responded to a range of audiovisual stimuli during cycle ergometer exercise. The stimuli comprised music, video, music-video, 360-degree video and 360-degree video with music. Moreover, we examined the effects of the aforementioned audiovisual stimuli on exercise at the VT, an intensity that it characterized by large affect-related interindividual variability. The dependent measures spanned affective (affective valence and perceived activation), perceptual (state attention and RPE), and enjoyment variables.

Affective Variables

We predicted that 360-degree video with music and 360-degree video conditions would facilitate the most positive affective valence and highest perceived activation (H_1). Furthermore, we hypothesized that music-video, music, and video conditions would elicit more positive affective valence and higher perceived activation when compared to the control condition (H_1). This expected outcome was observed for perceived activation, providing only partial support for H_1. This finding reinforces the notion that introducing audiovisual stimuli within an exercise environment appears to enhance perceived activation when compared to control conditions.[20,26] An original contribution of the present study concerns the heightened perceived activation in conditions that included 360-degree video. It is possible that the novelty of using a VR HMD might have contributed to this finding, given that the most pronounced differences in perceived activation were observed during the exercise bout, the time during which participants experienced the experimental manipulation (Figure 1a).

No statistical differences in affective valence emerged across conditions and this was an unexpected finding that precluded full acceptance of H_1 (Figure 1b). Contrastingly, researchers have demonstrated that the use of auditory[19] and audiovisual[50] stimuli can positively influence exercisers' affective valence during exercise. It is noteworthy that the 360-degree video with music condition elicited the highest ratings of affective valence *and* variation during the exercise bout (ie, from 7-17 min; $M = 3.13 \pm 1.53$). The observed variation in affective valence scores in this condition might have been caused, in part, by simulation sickness, which is a possible side effect of VR HMD use.[27,51]

An alternative explanation for the lack of differences across all conditions pertains to the participants recruited for the present study, the vast majority of whom were young, healthy, exercise science majors or recent graduates (cf.[22]). It is likely that these participants had a high degree of physical self-efficacy, which might have influenced their ability to tolerate or even prefer exercising at the VT, an intensity that usually elicits a range of affective responses.[13] The characteristics of the sample employed herein might help to explain the positive affective valence scores observed in the control condition during the exercise bout (ie, from 7-17 min; $M = 2.83 \pm 1.15$).

We expected the control condition to be associated with the most pronounced affective rebound (H_2), owing to participants' less positive in-task affective state. The greatest difference in affective valence scores from the final in-task measurement (ie, after 16 min) to the final post-task measurement (ie., after 25 min) was observed in the music condition ($M_{\text{diff}} = 1.78$) and therefore H_2 was not accepted. It is noteworthy that affective rebounds across conditions were of a similar magnitude (M_{diff} range = 1.45-1.78) and this was reflected in the nonsignificant condition × time interaction observed for affective valence (Figure 1b). Despite the nonacceptance of H_2, the present findings do provide support for the notion that a robust rebound toward pleasure is expected following the cessation of exercise that has induced an affective decline.[22] It is also worth highlighting that cooldown compared to the end of the bout was associated with a large effect size for affective valence (d = 0.94).

Perceptual Variables

We hypothesized that conditions containing 360-degree video would facilitate the most dissociative thoughts and lowest RPE. We also expected music-video, music, and video conditions to engender more dissociative thoughts and lower RPE when compared to the control condition (H_3). This predicted outcome was observed for state attention only, providing partial support for H_3. The finding that an audiovisual stimulus can prompt more dissociative thoughts than a sole stimulus (eg, music or video) is supported by previous research.[22,25] However, this is the first study in the exercise science literature to demonstrate that 360-degree video footage administered via a VR HMD can facilitate a greater number of dissociative thoughts when compared to audiovisual stimuli delivered via traditional displays (eg, television screens).

For RPE, no statistical differences emerged across conditions and this was somewhat unexpected (H_3). When considered alongside the state attention data, the findings indicate that participants were dissociating more in conditions that comprised 360-degree video footage, however their psychophysical state was not modulated by the experimental manipulation. This finding stands in opposition to a growing body of literature that has demonstrated that audiovisual stimuli can alleviate perceptions of exertion during exercise.[25,38] A plausible explanation for the unexpected RPE findings might be attributed to the type of action depicted in the video during the experimental conditions. We chose to employ video footage that was congruent with the exercise modality under investigation (ie, cycle ergometry). Contrastingly, researchers who have reported reductions in RPE have employed video footage such as circus performances[25] and music-videos,[38] both of which were incongruent with their associated exercise protocols. Accordingly, it is possible that using 360-degree video that is unrelated to the task at hand (eg, 360-degree music-videos) might have reduced participants' RPE to a greater degree than reported herein. However, it should be noted that participants' RPE scores were relatively low across all conditions (M = 3.80 ± 0.18), indicating that they perceived the exercise to be of a light-to-moderate intensity, regardless of the condition to which they were exposed.

Perceived Enjoyment

We predicted that participants would derive the greatest perceived enjoyment in conditions that contained 360-degree video. Furthermore, we expected music-video, music, and video conditions to elicit greater perceived enjoyment when compared to control (H_4). The main effect of condition revealed that the greatest perceptions of enjoyment was derived in the 360-degree video with music condition followed by the music-video condition, providing partial support for H_4. The finding that audiovisual stimuli can enhance exercise-related enjoyment is supported by previous work.[20,26] Nonetheless, this is the first study to demonstrate the enjoyment-inducing effects of 360-degree video footage delivered via a VR HMD during exercise. These findings are encouraging given that exercise-related enjoyment has been suggested to be a key determinant of exercise adherence.[52]

Theoretical and Practical Implications

From a theoretical perspective, these results illustrate the efficacy of employing audiovisual stimuli as a means by which to enhance affective responses to exercise at the VT. This is noteworthy because exercising at the VT is associated with large interindividual variability in affect, depicted by an inflection point on the dual-mode theory of exercise-related affect.[13] In addition to enhancing affective responses during exercise, researchers have postulated that *remembered pleasure* (ie, how pleasant or unpleasant an exercise bout is remembered), is a key factor in determining whether a behavior will be repeated.[17] Accordingly, the perceived enjoyment data derived from the PACES[45] supports the notion that audiovisual stimuli might be used to good effect in helping individuals adhere to exercise.

One of the mechanisms underlying the effects of audiovisual stimuli on exercise is attentional processing.[35] Load theory holds that perception is a limited-capacity process that proceeds automatically until that capacity is reached.[53] Tasks that involve high perceptual load leave little room for the processing of unattended information. Contrastingly, tasks that involve low perceptual load do not fully consume perceptual capacity, resulting in the processing of all available stimuli (ie, attended and unattended). In an exercise context, such unattended stimuli could refer to the physiological sensations that typically accompany exercise at the VT (eg, muscle acidosis).[22]

It is possible that audiovisual stimuli administered via VR HMDs can induce a higher perceptual load on exercisers when compared to traditional displays (eg, television screens). This is because modern VR HMDs are considered to be more immersive than traditional displays and can therefore facilitate greater perceptions of presence (ie, the psychological sense of being in the virtual environment).[27,28] Accordingly, the use of VR HMDs might be particularly potent at exercise intensities proximal to VT, as the physiological sensations associated with fatigue begin to compete for attentional resources.[13]

From a practical perspective, these results provide exercise and health practitioners with a viable solution for enhancing the affective responses of individuals who are exercising at VT. The implications of these results for public health are grounded in the emerging support pertaining to a positive relationship between affective responses and exercise adherence.[9] Given the lack of progress made toward reducing physical inactivity,[3] a strong case can be advanced for such interventions if we, as a society, are to derive the numerous physical and mental health benefits associated with regular engagement in exercise. Although employing audiovisual interventions via traditional displays has the advantage of cost effectiveness, the increasing rate at which VR HMDs are becoming widely accessible (eg, via a smartphone), means that virtual experiences will be readily available to a huge consumer audience in the near future.[51] Moreover, employing audiovisual stimuli in an exercise context has the advantage of requiring no previous training when compared to other psychological interventions such as cognitive reframing or imagery.[26]

Strengths and Limitations

An original contribution of this work pertains to the examination of 360-degree video footage delivered via a VR HMD during exercise. There is substantial interest in the use of VR technology and a plethora of applications are now available for consumers to download and experience instantly. However, the chronic effects of using VR technology remain relatively unknown.[54] Therefore, an examination of this technology in a controlled environment appears timely. The findings of the present study stand on the shoulders of an evolving corpus of literature that has employed traditional displays (eg, television screens, projectors) as a means of investigating audiovisual stimuli in an exercise context.[22,26]

We employed a rigorous music selection process to ensure that the motivational qualities of the tracks used in the experimental trials were homogenous, given that a lack of homogeneity has been suggested to pose a threat to internal validity in related studies.[26,38] The assessment of each participant's VT prior to conducting the experimental trials represents another strength. Defining exercise intensity according to physiological markers such as VT is preferable to that of percentage of heart rate max (HR_{max}), as it reduces interindividual variability in metabolic state when responding to measures of affect.[50] Finally, we included a range of conditions to account for every possible eventuality that individuals might encounter in an exercise context. This allowed us to draw comparisons between audio and visual stimuli used singularly and in combination (cf.[38]).

In terms of limitations, our power analysis was predicated on one dependent variable (ie, affective valence) but it might have been more appropriate to adopt a more conservative approach (ie, draw upon the smallest expected effect across all dependent variables). A minor point of concern was the observed difference in perceived activation scores between exercise trial 1 and trial 5 (Table S2). It is likely that this difference was manifest as a consequence of perfect counterbalancing not being possible, owing to the complexity of the present design. Furthermore, it could have been difficult for participants to respond to the psychological scales while wearing the VR HMD. As a means of reducing the impact of this limitation, we fully familiarized each participant with the psychological scales upon entry to the laboratory and the first author administered the scales verbally in conditions that required the VR HMD. Moreover, we delivered the music content via bone-conducting headphones, which enabled participants to listen to the music while simultaneously listening to the vocal instructions of the experimenter.

The present sample largely comprised young adults who were either exercise science majors or recent graduates, which might explain the positive affective valence scores observed across all conditions. Accordingly, the findings cannot be readily generalized to other populations without replication of the present study using a sample that is more representative of the wider population. Nevertheless, the study provides an initial examination into the effects of audiovisual stimuli at the VT and the findings can be used to spark research with other populations; in particular "at-risk" populations such as the obese or people with type 2 diabetes.[22]

Future Directions

The present study serves as a catalyst for several lines of future research. From a practical perspective, a useful addition to this line of research would be to examine a range of 360-degree videos (eg, music-videos, documentaries) in order to determine which has the most potent influence in terms of affective responses to exercise. Furthermore, researchers might assess individuals' perceptions of presence when exposed to 360-degree videos in an exercise context. It is plausible that incongruent video footage would represent a more potent form of dissociation technique when individuals are engaged in exercise. Given the volume of 360-degree content that is readily available from online libraries such as *YouTube Virtual Reality* and *Jaunt*, this represents a rather pragmatic extension of the present study.

From a methodological point of view, future work might include a broader range of exercise modalities than that examined here (eg, rowing, circuit training). However, caution is urged when employing VR HMDs in an exercise context, as there is great potential for individuals to collide with objects in the physical world. Moreover, there is risk of eyestrain when using VR HMDs over prolonged periods.[51] Researchers might also employ other exercise intensities, such as those predicated on ramp-down protocols,[17] or self-paced exercise.[19] From a mechanistic perspective, researchers are encouraged to examine the brain mechanisms that underlie the effects of audiovisual stimuli in an exercise context. Such explorations might include noninvasive methods such as electroencephalography that embrace active shielding technology, as a means of reducing the influence of movement artifacts.[20]

Perspectives

The current findings demonstrate that audiovisual stimuli delivered via a VR HMD have the capacity to positively influence the affective experience of exercise. This was evident through participants reporting greater perceived activation, more dissociative thoughts, and higher exercise enjoyment. Given the recent emphasis on affective responses to exercise as determinants of future behavior,[19] audiovisual stimuli should be considered as a valuable tool to help promote an enjoyable exercise experience.

References

1. Riebe D, Ehrman JK, Liguori G, Magal M, eds. *Guidelines for Exercise Testing and Prescription*. 10th ed. Philadelphia, PA: Wolters Kluwer; 2018.
2. World Health Organization. *Global Action Plan for the Prevention and Control of NCDs 2013-2020*. Geneva, Switzerland: WHO Document Production Services; 2013.
3. Foster C, Shilton T, Westerman L, Varney J, Bull F. World Health Organisation to develop global action plan to promote physical activity: Time for action. *Br J Sports Med*. 2018;52:484-485.
4. Sallis JF, Bull F, Guthold R, et al. Progress in physical activity over the Olympic quadrennium. *Lancet*. 2016;388:1325-1336.
5. Ekkekakis P, Zenko Z. Escape from cognitivism: Exercise as hedonic experience. In: Raab M, Wylleman P, Seiler R, Elbe A-M, Hatzigeorgiadis A, eds. *Sport and Exercise Psychology Research: From Theory to Practice*. London, UK: Academic Press; 2016:389-414.
6. Ekkekakis P. People have feelings! Exercise psychology in paradigmatic transition. *Curr Opin Psychol*. 2017;16:84-88.
7. Zenko Z, Ekkekakis P, Kavetsos G. Changing minds: Bounded rationality and heuristic processes in exercise-related judgments and choices. *Sport Exerc Perform Psychol*. 2016;5:337-351.
8. Kahneman D. Objective Happiness. In: Kahneman D, Diener E, Schwarz N, eds. *Well-Being: The Foundations of Hedonic Psychology*. New York, NY: Russell-Sage; 1999:3-25.

9. Williams DM, Dunsiger S, Emerson JA, Gwaltney CJ, Monti PM, Miranda R. Self-paced exercise, affective response, and exercise adherence: A preliminary investigation using ecological momentary assessment. *J Sport Exerc Psychol*. 2016;38:282-291.

10. Decker ES, Ekkekakis P. More efficient, perhaps, but at what price? Pleasure and enjoyment responses to high-intensity interval exercise in low-active women with obesity. *Psychol Sport Exerc*. 2017;28:1-10.

11. Rhodes RE, Fiala B, Conner M. A review and meta-analysis of affective judgments and physical activity in adult populations. *Ann Behav Med*. 2009;38:180-204.

12. Russell JA, Feldman Barrett L. Core affect. In: Sander D, Scherer KR, eds. *The Oxford Companion to Emotion and the Affective Sciences*. New York, NY: Oxford University Press; 2009:104.

13. Ekkekakis P. Pleasure and displeasure from the body: Perspectives from exercise. *Cogn Emot*. 2003;17:213-239.

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

15. Ekkekakis P, Zenko Z, Ladwig MA, Hartman ME. Affect as a potential determinant of physical activity and exercise. In: Williams DM, Rhodes RE, Conner MT, eds. *Affective Determinants of Health Behavior*. New York, NY: Oxford University Press; 2018:237-261.

16. Rhodes RE, Kates A. Can the affective response to exercise predict future motives and physical activity behavior? A systematic review of published evidence. *Ann Behav Med*. 2015;49:715-731.

17. Zenko Z, Ekkekakis P, Ariely D. Can you have your vigorous exercise and enjoy it too? Ramping intensity down increases postexercise, remembered, and forecasted pleasure. *J Sport Exerc Psychol*. 2016;38:149-159.

18. Carlier M, Delevoye-Turrell Y. Tolerance to exercise intensity modulates pleasure when exercising in music: The upsides of acoustic energy for high tolerant individuals. *PLoS One*. 2017;12:e0170383.

19. Hutchinson JC, Jones L, Vitti SN, Moore A, Dalton PC, O'Neil BJ. The influence of self-selected music on affect-regulated exercise intensity and remembered pleasure during treadmill running. *Sport Exerc Perform Psychol*. 2018;7:80-92.

20. Bigliassi M, Karageorghis CI, Hoy GK, Layne GS. The way you make me feel: Psychological and cerebral responses to music during real-life physical activity. *Psychol Sport Exerc*. 2019;41:211-217.

21. Karageorghis CI, Ekkekakis P, Bird JM, Bigliassi M. Music in the exercise and sport domain: Conceptual approaches and underlying mechanisms. In: Lesaffre M, Maes Pieter-J, Leman M, eds. *Routledge Companion to Embodied Music Interaction*. New York, NY: Routledge; 2017:284-293.

22. Hutchinson JC, Karageorghis CI, Black JD. The Diabeates Project: Perceptual, affective and psychophysiological effects of music and music-video in a clinical exercise setting. *Can J Diabetes*. 2017;41:90-96.

23. Bigliassi M, Silva VB, Karageorghis CI, Bird JM, Santos PC, Altimari LR. Brain mechanisms that underlie the effects of motivational audiovisual stimuli on psychophysiological responses during exercise. *Physiol Behav*. 2016;158:128-136.

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

25. Chow EC, Etnier JL. Effects of music and video on perceived exertion during high-intensity exercise. *J Sport Heal Sci*. 2017;6:81-88.

26. Jones L, Karageorghis CI, Ekkekakis P. Can high-intensity exercise be more pleasant? Attentional dissociation using music and video. *J Sport Exerc Psychol*. 2014;36:528-541.

27. Slater M, Sanchez-Vives M V. Enhancing our lives with immersive virtual reality. *Front Robot AI*. 2016;3:74.

28. Bailey JO, Bailenson JN. Considering virtual reality in children's lives. *J Child Media*. 2017;11:107-113.

29. Slater M, Wilbur S. A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence Teleoperators Virtual Environ*. 1997;6:603-616.

30. Cummings JJ, Bailenson JN. How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. *Media Psychol*. 2016;19:272-309.

31. Schmitt YS, Hoffman HG, Blough DK, et al. A randomized, controlled trial of immersive virtual reality analgesia, during physical therapy for pediatric burns. *Burns*. 2011;37:61-68.

32. Gold JI, Mahrer NE. Is virtual reality ready for prime time in the medical space? A randomized control trial of pediatric virtual reality for acute procedural pain management. *J Pediatr Psychol*. 2018;43:266-275.

33. Tashjian VC, Mosadeghi S, Howard AR, et al. Virtual reality for management of pain in hospitalized patients: Results of a controlled trial. *JMIR Ment Heal*. 2017;4:e9.

34. Zeng N, Pope Z, Gao Z. Acute effect of virtual reality exercise bike games on college students' physiological and psychological outcomes. *Cyberpsychology, Behav Soc Netw*. 2017;20:453-457.

35. Karageorghis CI. *Applying Music in Exercise and Sport*. Champaign, IL: Human Kinetics; 2017.

36. Karageorghis CI, Priest D-L, Terry PC, Chatzisarantis NLD, Lane AM. Redesign and initial validation of an instrument to assess the motivational qualities of music in exercise: The Brunel Music Rating Inventory-2. *J Sports Sci*. 2006;24:899-909.

37. Faul F, Erdfelder E, Buchner A, Lang A-G. Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behav Res Methods*. 2009;41:1149-1160.

38. Hutchinson JC, Karageorghis CI, Jones L. See hear: Psychological effects of music and music-video during treadmill running. *Ann Behav Med*. 2015;49:199-211.

39. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Mahwah, NJ: Lawrence Erlbaum Associates; 1988.

40. Warburton DER, Jamnik VK, Bredin SSD, et al. Evidence-based risk assessment and recommendations for physical activity clearance: An introduction. *Appl Physiol Nutr Metab*. 2011;36:S1-S2.

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

42. Svebak S, Murgatroyd S. Metamotivational dominance: A multimethod validation of reversal theory constructs. *J Pers Soc Psychol*. 1985;48:107-116.

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

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

45. Kendzierski D, DeCarlo KJ. Physical Activity Enjoyment Scale: Two validation studies. *J Sport Exerc Psychol*. 1991;13:50-64.

46. Beaver WL, Wasserman K, Whipp BJ. A new method for detecting anaerobic threshold by gas exchange. *J Appl Physiol*. 1986;60:2020-2027.

47. Tabachnick BG, Fidell LS. *Using Multivariate Statistics*. 7th ed. Essex, UK: Pearson Education; 2018.

48. Field A. *Discovering Statistics Using IBM SPSS Statistics*. 5th ed. London, UK: SAGE; 2018.

49. Nevill A, Lane AM. Why self-report "Likert" scale data should not be log-transformed. *J Sports Sci*. 2007;25:1-2.

50. Bird JM, Hall J, Arnold R, Karageorghis CI, Hussein A. Effects of music and music-video on core affect during exercise at the lactate threshold. *Psychol Music*. 2016;44:1471-1487.

51. Bailenson JN. *Experience on Demand: What Virtual Reality Is, How It Works, and What It Can Do*. New York, NY: W.W. Norton & Company; 2018.

52. Stork MJ, Kwan MYW, Gibala MJ, Martin Ginis KA. Music enhances performance and perceived enjoyment of sprint interval exercise. *Med Sci Sport Exerc*. 2015;47:1052-1060.

53. Murphy G, Groeger JA, Greene CM. Twenty years of load theory—Where are we now, and where should we go next? *Psychon Bull Rev*. 2016;23:1316-1340.

54. Madary M, Metzinger TK. Recommendations for good scientific practice and the consumers of VR-technology. *Front Robot AI*. 2016;3:3.

Table 1 Inferential statistics for all dependent variables

	Pillai's Trace	*F*	*df*	*P*	η_p^2
Affective Variables					
Condition x Time	.207	1.96	60, 1020	.000	.10
Affective Valence	-	1.61	5, 92	.160	.09
Perceived Activation	-	2.34	9, 145	.019	.12
Condition	.209	1.99	10, 170	.038	.11
Affective Valence	-	.55	3, 52	.654	.03
Perceived Activation	-	3.94	5, 85	.003	.19
Time	.899	13.88	12, 204	.000	.45
Affective Valence	-	26.88	2, 34	.000	.61
Perceived Activation	-	77.29	2, 31	.000	.82
Perceptual Variables					
Condition x Time	.083	.74	20, 340	.787	.04
Attention	-	1.10	5, 77	.365	.06
Perceived Exertion	-	.34	5, 80	.880	.02
Condition	.396	4.20	10, 170	.000	.20
Attention	-	7.73	3, 49	.000	.31
Perceived Exertion	-	1.28	5, 85	.280	.07
Time	.400	4.24	4, 68	.004	.20
Attention	-	1.36	1, 22	.266	.07
Perceived Exertion	-	9.74	1, 21	.004	.36
Perceived Enjoyment					
Condition	-	4.26	3, 47	.011	.20

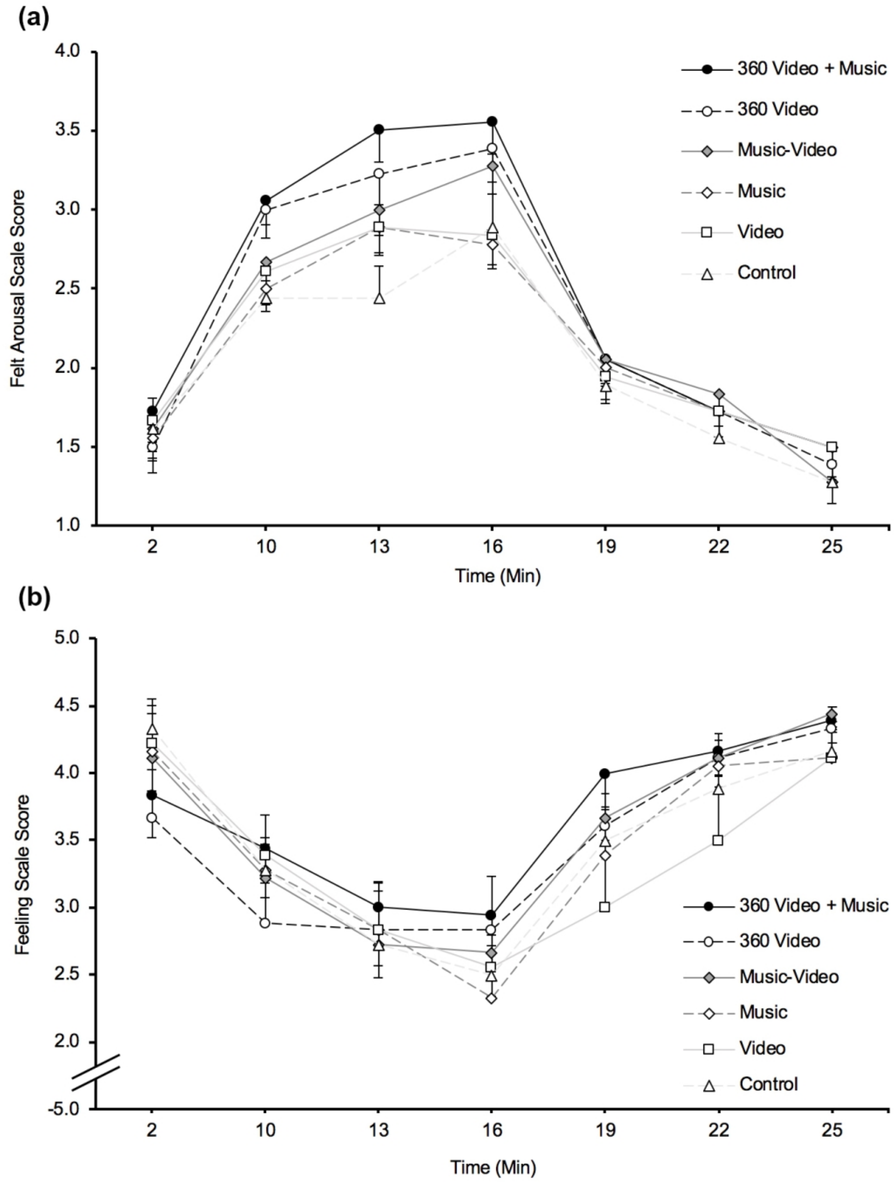

Figure 1 Felt Arousal Scale (FAS; a) and Feeling Scale (FS; b) responses (M and SE) across conditions.

244x317mm (144 x 144 DPI)

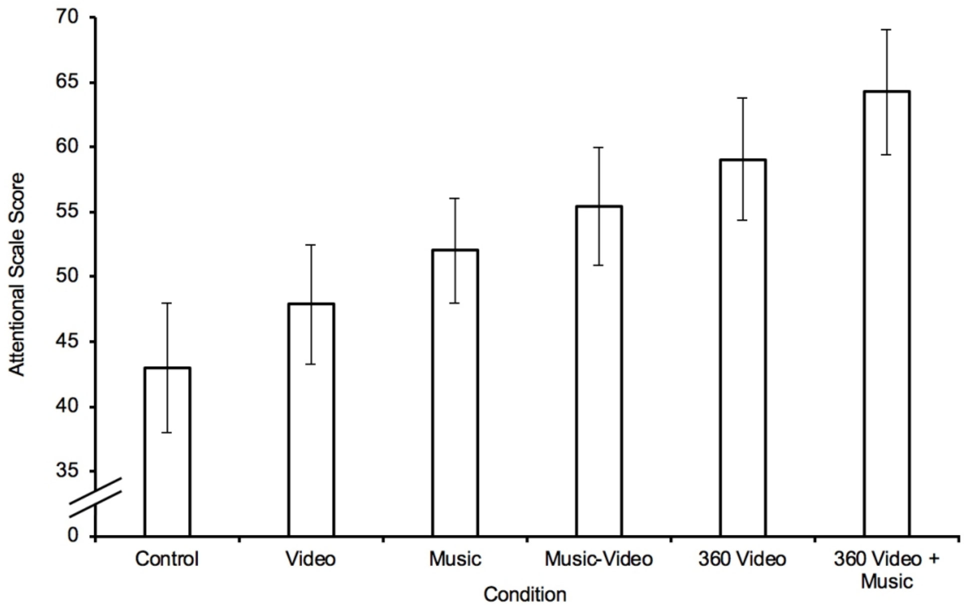

Figure 2 Attentional Scale responses (M and SE) across conditions.

242x152mm (144 x 144 DPI)

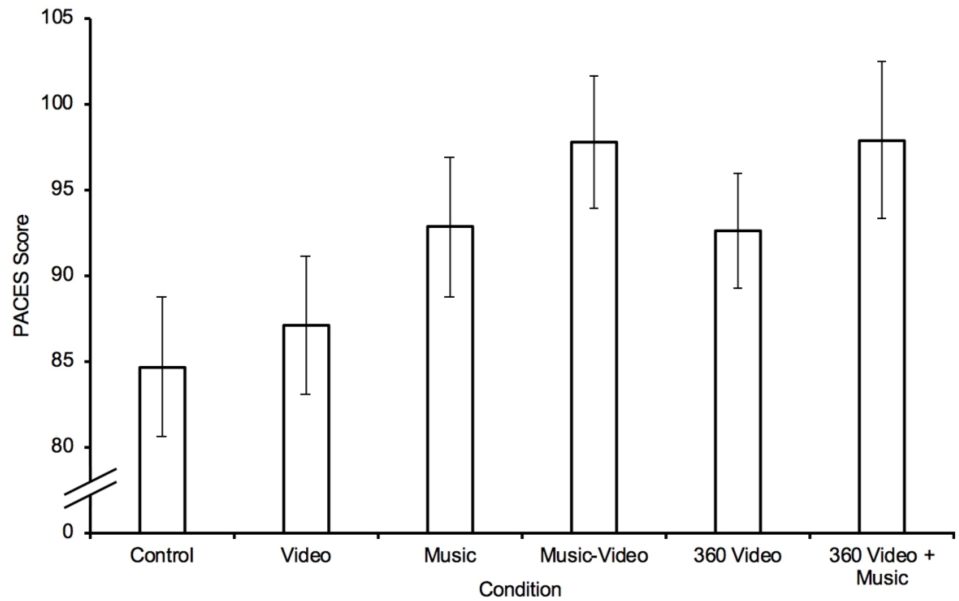

Figure 3 Physical Activity Enjoyment Scale responses (M and SE) across conditions.

242x152mm (144 x 144 DPI)