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Effects of Audiovisual Stimuli on Psychological Responses during Exercise in Obese Adults

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Abstract

Objective: The present experiment sought to further understanding of the effects of personalised audiovisual stimuli on psychological and psychophysiological responses during self-paced exercises in obese adults. *Methods:* Twenty-four participants ($M_{age} = 28.3$, $SD = 5.5$ years; $M_{BMI} = 32.2$, $SD = 2.4$) engaged in self-paced exercises on a recumbent cycle ergometer and three conditions (sensory stimulation [ST], sensory deprivation [DE], and control [CO]) were administered. Perceptual (attentional focus and perceived exertion), affective (affective state and perceived activation), and psychophysiological (heart rate variability) parameters were monitored throughout the exercise bouts. *Results:* ST increased the use of dissociative thoughts throughout the exercise bout, and this was associated with a large effect size ($\eta_p^2 = .19$). The audiovisual stimuli also ameliorated fatigue-related sensations ($\eta_p^2 = .15$) and induced more positive affective responses ($\eta_p^2 = .12$) than CO and DE. Perceived activation and heart rate variability indices were not influenced by both time and condition factors. *Conclusions:* The results of the present study indicate that personally-compiled videos are highly effective in ameliorating exertional responses and enhancing affective valence during self-paced exercise in obese adults. Audiovisual stimuli could be used during the most critical periods of the exercise regimen when obese individuals are more likely to focus on internal sensory information and disengage from physical activity programmes. The results of the present study have important implications for exercise adherence and obesity treatment.

Keywords: applied psychology, attention, motor activity, psychophysiology, sensory aids

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Excess body weight represents one of the biggest threats to the world population, and mathematical models estimate a concerning growth of this problem over the next years (for details, see Wang & Beydoun, 2007). Overweight and obesity are hot topics in social media and political debates. Every year billions of dollars are spent in an attempt to counteract the detrimental effects of obesity on the health of adults and children (see Hammond & Levine, 2010). Excess body weight is also considered the biggest “killer” of all times and is related to cardiovascular diseases, osteoarticular and psychophysiological problems (Abdullah et al., 2014).

Due to the devastating problems caused by excess body fat, researchers have been attempting to further understanding of psychosocial and psychophysiological mechanisms that underlie this phenomenon. Compelling evidence indicates that diet problems related to a high consumption of fat, meat, and processed foods are the main reasons by which people gain weight so fast (cf. Swinburn, Caterson, Seidell, & James, 2004; Wang & Beydoun, 2009). However, total daily energy expenditure also appears to influence visceral and subcutaneous fat (Shields & Tremblay, 2008). Accordingly, a sedentary lifestyle contributes to body weight gain (Heinonen et al., 2013) and is directly associated with pulmonary complications, circulatory problems, and psychological disorders (Caballero, 2007).

A decrease in the time spent physically inactive has been shown to be an important aspect in reducing subcutaneous and visceral fat when combined with diet re-education programmes (Villareal et al., 2011). Unfortunately, light-to-moderate-intensity bouts of physical activities are commonly perceived to be highly fatiguing in obese individuals; this is due to the extra weight they carry (i.e., subcutaneous fat). Overweight and obese individuals also tend to report higher levels of osteoarticular pain (Zdziarski, Wasser, & Vincent, 2015) during the execution of physical tasks in comparison with healthy individuals. The result of

this powerful combination of cognitive processes usually prompts high levels of demotivation, which subsequently leads to exercise disengagement (Colombo et al., 2014).

Attention, Exercise, and Pleasure

Exertional responses experienced during the execution of movements such as breathlessness and limb discomfort have been theorised to be *simple* creations of the human brain, only moderated by internal sensory cues (e.g., muscle afferent signals; Rejeski, 1985). Based on this assumption, perceived effort (i.e., how hard one perceives the task at hand) can be considered to be a conscious and active process, primarily “created” by electrical signals in the brain (Bigliassi, 2015a; Bigliassi, Karageorghis, Wright, Orgs, & Nowicky, 2017). In such instances, interoceptive sensory signals only serve to increase fatigue-related sensations and have a detrimental effect on exercise performance. This mechanism has been suggested to induce a resting state and lead participants towards task disengagement (Bigliassi, Karageorghis, Nowicky, Orgs, & Wright, 2016). Interestingly, environmental sensory cues appear to increase the use of dissociative thoughts, optimise control of movements, and ameliorate the detrimental effects of fatigue on exercise (Clark, Baker, & Taylor, 2016; Gabana, Van Raalte, Hutchinson, Brewer, & Petitpas, 2015). Put another way, external influences such as music and video have the potential to force attention towards task-unrelated factors, assuage fatigue, and make a given activity more pleasant than under normal circumstances.

Rationale for the Present Study

In theory, bouts of physical exercise can be sustained for long periods of time and at relatively high-intensities, even for individuals with excess body fat (Mcqueen, 2009). However, interoceptive sensory cues tend to force attention towards internal association (N. Brick, Macintyre, & Campbell, 2014) and disrupt exercise performance (Lohse & Sherwood, 2012; Rejeski, 1985). Accordingly, fatigue-related sensations appear to have a

disproportionate effect on overweight and obese individuals (Ekkekakis & Lind, 2006) during the execution of whole-body exercise modes. For the long term, individuals with excess body fat tend to accumulate negative affective memories and relate the execution of movements with pain, weariness, and displeasure (Deforche & De Bourdeaudhuij, 2015). Interestingly, pleasant environmental stimuli appear to partially counteract the detrimental effects of fatigue, facilitate control of working muscles, and enhance affective responses during exercise (Barwood, Weston, Thelwell, & Page, 2009; Georgios Loizou, Karageorghis, & Bishop, 2014). Thus, the aim of the present study was to investigate the psychological and psychophysiological effects of pleasant audiovisual stimuli during the execution of cycling exercises performed at self-selected intensities in obese individuals.

Research Hypotheses

We hypothesised that the audiovisual stimuli would reallocate attentional focus towards external influences, preventing afferent signals from entering focal awareness (for review, see Karageorghis, 2017). The presence of environmental sensory stimuli was also hypothesised to facilitate control of movements (i.e., a more autonomous activation of working muscles) and induce more positive affective responses when compared to a control condition (e.g., Pates, Karageorghis, Fryer, & Maynard, 2003; Terry, Karageorghis, Mecozzi Saha, & D'Auria, 2012). Finally, the physiological stress (see Heart Rate Variability section) imposed by the execution of movements was also expected to be ameliorated in the presence of audiovisual stimuli (cf. Bigliassi, León-Domínguez, Buzzachera, Barreto-Silva, & Altimari, 2015).

Method

This is a randomised controlled trial that made use of a counterproof method (see Experimental Procedures section) to identify the effects of sensory manipulation on psychological responses and psychophysiological reactions. The experimental phases of the

present study were conducted on two occasions (~120 min in total) and participants were assessed separately in order to avoid inter-individual comparisons. Only non-invasive techniques (i.e., questionnaire, scales, and a heart rate monitor) were employed in the present experiment. This study was approved by the Institutional Ethics Research Committee.

Participants

Affective responses to exercise were used as central parameters on G*Power 3.1.3 (Faul, Erdfelder, Lang, & Buchner, 2007) to identify the required sample size (Hutchinson, Karageorghis, & Jones, 2015). The software indicated that 23 participants would be necessary ($\alpha = .05$; $1 - \beta = .75$; $f = .26$). Accordingly, one additional participant was recruited in order to compensate likely experimental mortality (total sample = 24; $M_{age} = 28.3$, $SD = 5.5$ years; $M_{height} = 1.67$, $SD = .7$; $M_{weight} = 90.7$, $SD = 9.6$, $M_{BMI} = 32.2$, $SD = 2.4$) and facilitate a fully counterbalanced design. Participants were mainly approached through the use of institutional emails and posters. Those who demonstrated an interest in taking part were initially surveyed by the present research team. Sociodemographic and anthropometric indices were assessed during the pre-experimental phase (see Experimental procedures section). The body mass index (BMI; i.e., $\text{weight}/(\text{height})^2$) was used as a means by which to classify participants according to their nutritional status (“Obesity: Preventing and managing the global epidemic. Report of a WHO consultation.,” 2000). The person’s physical activity level was assessed by use of the *International Physical Activity Questionnaire* (IPAQ – short version; Lee, Macfarlane, Lam, & Stewart, 2011). Only those considered minimally active or inactive and obese ($30 \text{ kg/m}^2 \leq \text{BMI} \leq 40 \text{ kg/m}^2$) took part in the present study. Participants also had the opportunity to read the participant information sheet, sign the informed consent, complete the *Physical Activity Readiness Questionnaire* (PARQ), and ask the research team about any questions or concerns they could have prior to commencement of data collection.

Pre-Experimental Phase

Anthropometric tests were conducted to measure participants' height and weight. A pre-experimental semi-structured interview was subsequently administered as a means by which to identify hobbies, pleasurable activities and personal preferences. The semi-structured interview can be requested from the first author. This interview was conducted by the third and fourth authors of the present study. Thematic analysis and coding techniques were employed by three members of the research team after transcription of participants' responses as a means by which to create themes and topics of interests (Ryan & Bernard, 2003). Three members of the research team analysed each participant's answers and compared general dimensions obtained on sentences with the video created by a fourth researcher (Braun & Clarke, 2006). A 10-min video was created for each participant (i.e., personalised audiovisual stimuli) and used during the main experimental phase (see Experimental procedures section). This strategy was used to elicit the most positive psychological and psychophysiological changes, standardise emotional responses to different audiovisual stimuli, and enhance the experiment's internal validity (Bigliassi, 2015b).

Experimental Procedures

During the second visit to the laboratory participants were familiarised with the psychometric instruments (see Affective and Perceptual Measures section) and had a heart rate sensor (Polar H7) attached to their chests. Participants were subsequently asked to sit on a comfortable chair for 10 min in order to identify baseline values (i.e., heart frequency at the 10th min). Two experimental conditions (sensory stimuli [ST] and sensory deprivation [DE]) and a control condition (CO) were administered in the present study. DE was used to further understanding of extremely different patterns of stimulation on psychophysiological responses to exercise (i.e., a *counterproof* method; cf. Boutcher & Trenske, 1990) By reducing the influence of audiovisual feedback participants were hypothesised to focus more

intently on the task at hand. Internal association induced by sensory deprivation could, therefore, increase the use of associative thoughts, upregulate fatigue-related sensations, and have a detrimental effect on participants' affective states.

The order of administration was randomised and counterbalanced by use of a deterministic algorithm. A minimum 10-min period was used to allow participants to fully recover prior to commencing the next bout of physical activity. Furthermore, physiological (heart rate) and perceptual (perceived exertion) indices should be at the baseline level as a means by which to reduce the influence of the carry-over effects of fatigue on repeated bouts of exercise. In case of non-basal values, an extra 3-to-5-min period was used to re-establish participants' homeostasis.

Participants were administered three exercise bouts on a recumbent cycle ergometer (Movement) during 10 min each. The exercise was performed at a self-selected intensity and participants only received instructions to cycle at 60 to 90 revolutions per minute (RPM). Participants could also change the imposed resistance as they pleased. The distance covered during the test was used as a measure of exercise performance. The personalised audiovisual stimuli were created to divert attention from task-related signals to environmental sensory cues. Moreover, the stimulus should entertain, render a more positive affective state, increase produced power, assuage fatigue-related sensations (e.g., limb discomfort), and downmodulate sympathovagal balance (Karageorghis & Jones, 2014). A 52-inch screen (Sony) was placed right in front of the cycle ergometer information screen. Participants used headphones (Razer Kraken) to improve the sound quality and create an immersive environment. The sound intensity was kept at ~75 dBA measured by use of a decibel meter. A single-item liking scale was used at the end of the experiment to gauge the degree to which participants liked the auditory stimuli (Karageorghis, Jones, & Stuart, 2008).

Deprivation of auditory signals was ensured by using cottonball earplugs and noise cancelling headphones. Thus, the auditory sensory signals were blocked forcing attentional focus towards internal sensory cues. Researchers asked three personal questions (e.g., what is your name?) at ~90 dBA and 50 cm from the participant's ears to ensure complete blockage of auditory processing. In case of positive response, the research team applied stretchable elastic straps over the headphone to further improve auditory deprivation. The imposed exercise awareness was expected to increase the use of associative thoughts, upregulate fatigue-related symptoms, and make the exercise less enjoyable (Boutcher & Trenske, 1990). Two researchers were responsible for constantly monitoring of physiological, affective, perceptual, and performance-related indices throughout the experiment.

Affective and Perceptual Measures

Four psychological instruments were administered during the exercise bouts in order to further understanding of affective and perceptual responses to sensory modulation. The psychological measures were assessed five times during the exercise bout (.5 min, 2.5 min, 5 min, 7.5 min, and 9.5 min). Attentional focus (AF) was assessed by use of the *Single-Item Attention Scale* (0 to 100 arbitrary units) developed by Tammen (1996) This psychological instrument was developed to quantify attention allocation to internal (e.g., muscle acidosis) and external (e.g., visual stimuli) signals during exercise-related situations. Perceived exertion was assessed by use of the *Rate of Perceived Exertion* (RPE) developed by Borg (1982). A 15-point RPE scale (6–20 arbitrary units) was used to investigate an individual's perceived exertion during the exercise bouts.

Core affect was assessed by use of the *Feeling Scale* (FS) developed by Hardy and Rejeski (1989) and *Felt Arousal Scale* (FAS) developed by Svebak and Murgatroyd (1985). These instruments were used to investigate an individual's affective changes to exercise. FS is a single-item affect scale (11 points) varying from -5 (very bad) to +5 (very good). FS was

developed to assess the hedonic tone (i.e., degree of pleasantness or unpleasantness) of emotional responses during exercise sessions. FAS is a single-item arousal scale varying from 1 (low arousal) to 6 (high arousal). FAS was used to investigate one's perceived activation (i.e., psychophysiological arousal) during exercise. A single-item scale ranging from 1 (I do not like it at all) to 10 (I like it very much) was also used at the very end of the experiment in order to identify the degree to which participants liked the audiovisual stimuli (Karageorghis et al., 2008).

Heart Rate Variability

Heart frequency was continuously monitored throughout the exercise bouts as a means by which to explore the physiological stress imposed by exercise and sensory modulation. The heart's electrical signal was subsequently transferred to HRV Logger and imported to Kubios HRV. "The "strong filter" option was used to remove extraneous electrical artefacts during offline procedures (Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014). The Fast Fourier Transform method was used to decompose the electrical signals into different frequencies (i.e., frequency-domain analysis). Low-frequency components (.04 to .15 Hz) of the power spectrum were used as an index of global activity (i.e., sympathetic and parasympathetic activities). Conversely, high-frequency (.15 to 4 Hz) components of heart rate variability were used as an index of parasympathetic activity (for details, see Rajendra Acharya, Paul Joseph, Kannathal, Lim, & Suri, 2006).

Statistical Analyses

Univariate outliers were identified using standardised scores (i.e., > 3.29 or < -3.29 ; Tabachnick & Fidell, 2014) on IBM SPSS 22.0. Data normality was assessed using the Shapiro-Wilk test. Sphericity was assessed through the use of the Mauchly's test. Data transformations (e.g., square root) were applied in case of non-normal distribution in order to conduct parametric tests. A one-way repeated measures analysis of variance (ANOVA) was

used to compare performance (main effect [3 Conditions]), perceptual, affective, and psychophysiological variables (main and interaction effects [5 Timepoints x 3 Conditions]). Greenhouse-Geisser corrections were used in case of non-spherical data to adjust the degrees of freedom. Bonferroni adjustments were used to locate significant differences. Statistical significance level was set at .05.

Results

Nine univariate outliers (i.e., cell cases) were identified and duly removed from subsequent analyses. A non-normal distribution with a leptokurtic Gaussian shape and negative skew was identified for LF, which required a reflected transformation by use of square root corrections (see Tabachnick & Fidell, 2014, p. 87). Similarly, a non-normal distribution with a leptokurtic profile and positive skew was observed for HF. In this case, square root transformations were applied to adjust the Gaussian curve. After correcting the data, LF and HF presented normal profiles for all conditions and timepoints. It is also important to highlight that participants considered the personal videos to be highly enjoyable ($M_{liking\ rate} = 8.88$, $SD = 1.04$, $Min = 7$, $Max = 10$).

Interaction Effects

Perceptual responses. The predominant focus of attention differed significantly across conditions during the execution of a 10-min self-paced task (Condition*Time interaction effect: $W = .014$, $\varepsilon = .559$, $F[4.47, 102.79] = 5.41$, $p < .001$, $\eta_p^2 = .191$). Post hoc comparisons indicated that ST differed significantly from CO and DE ($p < .05$) at timepoints 2 (2.5 min), 3 (5 min), 4 (7.5 min), and 5 (9.5 min), and increased the use of dissociative thoughts throughout the exercise bouts (see Figure 1A). No significant differences were identified between CO and DE ($p > .05$).

The results of the present study also indicated that fatigue-related symptoms were ameliorated in the presence of audiovisual stimuli when compared to CO and DE. Interaction

effects indicated that ST had a positive influence on participants' perceived exertion

(Condition*Time interaction effect: $W = .009$, $\varepsilon = .464$, $F[3.71, 85.31] = 4.14$, $p = .005$, $\eta_p^2 = .153$). Pairwise comparisons indicated that ST differed significantly from DE at timepoints 2 and 3, and from CO and DE at timepoints 4 and 5 ($p < .05$; see Figure 1B).

Affective responses. Participants' affective states were significantly influenced by condition and time factors (Condition*Time interaction effect: $W = .013$, $\varepsilon = .597$, $F[4.77, 109.76] = 3.22$, $p = .010$, $\eta_p^2 = .123$). Multiple comparisons tests indicated that ST elicited more positive affective responses than DE ($p < .001$) at timepoint 2, and from CO and DE at timepoints 3, 4, and 5 ($p < .05$; see Figure 2A). No significant differences were observed between CO and DE at all timepoints ($p > .05$).

No significant Condition*Time interaction was identified for perceived activation (Condition*Time interaction effect: $W = .027$, $\varepsilon = .520$, $F[4.15, 95.63] = .93$, $p = .454$, $\eta_p^2 = .039$; see Figure 2B).

Psychophysiological responses. No significant Condition*Time interaction was identified for heart rate (Condition*Time interaction effect: $W = .001$, $\varepsilon = .364$, $F[2.91, 67.01] = 1.72$, $p = .171$, $\eta_p^2 = .070$; see Figure 3A), LF (Condition*Time interaction effect: $W = .012$, $\varepsilon = .533$, $F[4.27, 55.47] = .724$, $p = .587$, $\eta_p^2 = .053$; see Figure 3B), and HF (Condition*Time interaction effect: $W = .057$, $\varepsilon = .585$, $F[4.68, 107.65] = .826$, $p = .528$, $\eta_p^2 = .035$; see Figure 3C) components of heart rate variability.

Main Effects

Task performance. No significant differences were identified in task performance ($W = .902$, $F[2, 46] = 2.44$, $p = .098$, $\eta_p^2 = .096$). Put another way, the distance covered within 10 min was statistically similar across conditions ($M_{CO} = 3.49$ km, $SE = .08$; $M_{ST} = 3.66$ km, $SE = .10$; $M_{DE} = 3.54$ km, $SE = .09$).

Perceptual responses. The data indicated that time ($W = .087$, $\varepsilon = .462$, $F[1.84, 42.52] = 8.29$, $p = .001$, $\eta_p^2 = .265$) and condition ($W = .659$, $\varepsilon = .746$, $F[1.49, 34.3] = 25.42$, $p < .001$, $\eta_p^2 = .525$) factors had a significant influence on attentional focus (see Figure 1A). Multiple comparisons tests indicated that the attentional scores at the first timepoint (.5 min) differed significantly from the 3rd, 4th, and 5th timepoints. Also, the main effects indicated that ST differed from CO and DE ($p < .001$). No significant differences were identified between CO and DE ($p > .05$).

Exertional responses were significantly influenced by time ($W = .039$, $\varepsilon = .398$, $F[1.59, 36.63] = 44.54$, $p < .001$, $\eta_p^2 = .659$) and condition ($W = .977$, $F[2, 46] = 6.77$, $p = .003$, $\eta_p^2 = .228$) factors (see Figure 3). Post hoc tests indicated that all timepoints differed from one another ($p < .05$) with the exception of timepoints 4 and 5 ($p = .507$). Main effect comparisons also indicated that ST differed significantly from CO and DE ($p < .001$), however, no significant differences were identified between CO and DE ($p = .923$; see Figure 1B).

Figure 1

Affective responses. The results indicated that time ($W = .331$, $\varepsilon = .628$, $F[2.51, 57.73] = 11.09$, $p < .001$, $\eta_p^2 = .325$) and condition ($W = .885$, $F[2, 46] = 19.73$, $p < .001$, $\eta_p^2 = .462$) factors had a significant effect on affective valence (see Figure 2A). Post hoc analyses showed that all timepoints differed from one another with the exception of subsequent values (e.g., timepoint 2 was similar to 3 but different from 1, 4, and 5; $p < .05$). It has also been identified that ST differed significantly from CO and DE (i.e., main effects of condition factors; $p > .001$), but no differences were identified between CO and DE ($p = .483$).

Despite the absence of significant interaction effects for perceived activation, main effects for condition ($W = .965$, $F[2, 46] = 4.51$, $p = .016$, $\eta_p^2 = .164$) and time ($W = .037$, $\varepsilon =$

.374, $F[1.49, 34.44] = 5.38$, $p = .015$, $\eta_p^2 = .190$) factors have been identified. Pairwise comparisons indicated that ST differed significantly from DE ($p = .028$), but no differences were identified between ST and CO ($p = .227$), and CO and DE ($p = .841$). Interestingly, post hoc comparisons were not sufficiently sensitive to identify any differences across timepoints ($p > .05$; see Figure 2B).

Figure 2

Psychophysiological parameters. It has been identified that time ($W = .004$, $\epsilon = .315$, $F[1.26, 28.98] = 175.01$, $p < .001$, $\eta_p^2 = .884$) and condition ($W = .817$, $F[2, 46] = 10.35$, $p < .001$, $\eta_p^2 = .310$) factors had a statistically significant effect on heart rate (see Figure 3A). Post hoc comparisons indicated that all timepoints differed from one another with the exception of the timepoints 4 and 5 ($p > .05$). Also, heart rate values were greater for ST than CO and DE (i.e., main effects of condition factors; $p > .001$), but no differences were identified between CO and DE ($p > .05$).

LF components of the power spectrum were significantly influenced by time factors ($W = .245$, $F[4, 52] = 2.69$, $p = .041$, $\eta_p^2 = .172$). However, pairwise comparisons did not detect any significant differences across timepoints ($p > .05$; see Figure 3B). Also, condition factors were not sufficiently potent to influence the global activity of the autonomous system ($W = .739$, $F[2, 26] = .77$, $p = .473$, $\eta_p^2 = .056$).

Despite the absence of significant interactions between time and condition (see Interaction Effects section), these factors showed a main significant effect on HF (Time: $W = .154$, $\epsilon = .528$, $F[2.11, 48.58] = 5.72$, $p = .005$, $\eta_p^2 = .199$; Condition: $W = .955$, $F[2, 46] = 3.27$, $p = .047$, $\eta_p^2 = .125$). Multiple comparisons tests indicated that the first timepoint differed significantly from the others ($p < .05$), but no differences were observed across conditions ($p > .05$; see Figure 3C).

Figure 3

Discussion

The present experiment sought to investigate the effects of audiovisual stimuli on psychological and psychophysiological responses during self-paced exercises in obese adults. We initially hypothesised that ST would direct attention towards task-unrelated thoughts, which could subsequently prevent interoceptive sensory cues from entering focal awareness. The presence of environmental sensory stimuli was also hypothesised to facilitate control of working muscles and induce more positive affective responses when compared to CO and DE. Finally, the present research team hypothesised that the physiological stress imposed by the execution of movements could have been assuaged when participants exercised in the presence of audiovisual stimuli.

The present findings only partially support the hypotheses that were initially drawn by the research team (see Results section). ST increased the use of dissociative thoughts throughout the exercise bout, and this was associated with a large effect size ($\eta_p^2 = .19$). The audiovisual stimuli used in the present study also ameliorated fatigue-related sensations ($\eta_p^2 = .15$) and induced more positive affective responses ($\eta_p^2 = .12$) than CO and DE. However, participants' perceived activation was not influenced by both time and condition factors. This could be due to the fact that psychological and psychophysiological stresses experienced during exercise are primarily up-/down-regulated by the execution of movements (Bigliassi et al., 2015). In such instances, sensory stimulation/deprivation might have a very limited effect on participants' affective arousal (cf. Jones, Karageorghis, & Ekkekakis, 2014). A similar pattern of results has been identified for heart rate variability. Low- and high-frequency components of the power spectrum have not been significantly influenced by sensory manipulation (cf. Loizou & Karageorghis, 2015). It is also important to emphasise that the differences observed in heart rate (main effects) could have been influenced by the relatively higher intensity at which participants executed the motor task. Despite the fact that no

significant differences were identified in exercise performance, the distance covered within 10 min was ~5% longer in ST when compared to CO and DE.

The present results are in line with Jones et al.'s (2014) study, where 34 apparently healthy participants were exposed to cycle ergometry exercises at four different intensities. They have also utilised sensory stimuli (e.g., music and video) as a means by which to guide attention towards environmental sensory cues and reduce perceived exertion. The results of this study indicated that music-only and music-and-video conditions led to the highest valence and enjoyment scores during and after exercise regardless of intensity. In other words, attentional manipulations exerted a noticeable influence on participant's affective state and perceived enjoyment even during high-intensity exercises.

More recently, Hutchinson et al. (2015) administered different forms of audiovisual stimuli for 24 apparently healthy participants who exercised on a motorised treadmill at various intensities. The authors identified a Condition*Intensity*Time interaction effect for affective arousal and state motivation, and an Intensity*Time interaction for attention allocation, perceived exertion, and affective state. In the aforementioned study the combined music-and-video (i.e., audiovisual stimulation) condition yielded the highest levels of dissociation, lowest perceived exertion, and most positive affective responses regardless of exercise intensity. The authors also concluded that attentional manipulations using audiovisual stimuli can influence perceptual and affective variables at light-to-moderate- and moderate-to-severe-intensities.

Collectively, the studies of Jones et al. (2014) and Hutchinson et al. (2015) and the present findings support the use of audiovisual stimulation as a means by which to counteract the detrimental effects of fatigue on exercise execution and induce more positive affective responses. Combined auditory and visual signals have the potential to force attention towards external sensory cues and reduce exercise consciousness. This mechanism has been recently

hypothesised to optimise neural control of working muscles by reducing the frequency at which the brain emits efferent signals to the musculature (for details, see Bigliassi et al., 2017). It is also important to highlight that personally-compiled videos might have had a more pronounced effect than researcher-selected stimuli. This is because personalised stimuli are directly linked to the individual's interests and could also reawaken positive long-term memories that are beneficial for exercise execution and enjoyment.

Limitations

The use of sensory deprivation was not efficacious as previously hypothesised. DE had a more negative effect on perceptual and affective responses than CO and ST. However, these differences were not statistically significant (see Figures 1A, 1B, and 2A). The lack of differences observed in DE could have been associated with the partial suppression of sensory information that participants experienced during the exercise bout. The present authors decided to only block auditory signals by use of cottonball earplugs and noise-cancelling headphones. Complete blockage of sensory stimuli could have been more effective in inducing negative perceptual and affective responses. This could have been achieved by using blindfolds. However, it is noteworthy that blindfolds might limit task-related thoughts (e.g., changing the resistance imposed by the cycle ergometer) and compromise participants' understanding of psychometric measures that were used during the experimental protocol.

It is important to emphasise that the audiovisual stimuli used in the present study varied substantially in terms of physical features such as brightness, colour, timbre, and pitch. We also acknowledge that differences in physical features could have imposed a threat to internal validity (Karageorghis & Terry, 1997). However, the use of similar audiovisual stimuli commonly lead to unpredictable and variable psychological responses that are caused by the individual's interpretation of the stimulus. Conversely, personally-compiled stimuli are more likely to "standardise" emotional responses (see Results section) given the fact that the

videos are specially selected for each individuals based on their interests and preferences (Bigliassi, 2015b).

Conclusions

The results of the present study indicate that personally-compiled videos are highly effective in ameliorating exertional responses (e.g., breathlessness) and enhancing affective valence. Throughout the exercise bout, ST guided participants' attentional foci towards external influences and prevented negative affective responses. This could be indicative of a protective effect of external dissociation on the psychological stress induced by exercise-related situations (Brick, Campbell, Metcalfe, Mair, & MacIntyre, 2015). Interestingly, task performance and physiological stress were similar across conditions, meaning that audiovisual stimuli have the potential to facilitate neural control of working muscles through the amelioration of fatigue and enhancement of affective valence (Bigliassi, 2015a). Such interventions could be applied during the most critical periods of the exercise regimen when obese individuals are more likely to focus on internal sensory information and disengage from physical activity programmes. Accordingly, the results of the present study have important implications for exercise adherence and obesity treatment. Future research is necessary to develop and test new computer and smartphone applications to automatically produce personally-compiled videos that are representative of the individual's hobbies and interests.

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Figure Captions

Figure 1. Condition*Time interaction for perceptual responses. *Note.* A: Attentional focus; B: Rate of perceived exertion; CO = Control; ST = Sensory stimulation; DE = Sensory deprivation; Error bars represent standard error.

Figure 2. Condition*Time interaction for affective responses. *Note.* A: Affective valence; B: Perceived activation; CO = Control; ST = Sensory stimulation; DE = Sensory deprivation; Error bars represent standard error.

Figure 3. Condition*Time interaction for psychophysiological responses. *Note.* A: Heart rate; B: Low-frequency components (square root with reflection transformed data); C: High-frequency components (square root transformed data); CO = Control; ST = Sensory stimulation; DE = Sensory deprivation; bpm = Beats per minute; n.u. = Normalised units. Error bars represent standard error.