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Effects of psychological priming, video, and music on anaerobic exercise performance

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Peak performance videos accompanied by music can help athletes to optimize their pre-competition mindset and are often used. Priming techniques can be incorporated into such videos to influence athletes' motivational state. There has been limited empirical work investigating the combined effects of such stimuli on anaerobic performance. The present study examined the psychological and psychophysiological effects of video, music, and priming when used as a pre-performance intervention for an anaerobic endurance task. Psychological measures included the main axes of the circumplex model of affect and liking scores taken pre-task, and the Exercise-induced Feeling Inventory, which was administered post-task. Physiological measures comprised heart rate variability and heart rate recorded pre-task. Fifteen males (age = 26.3 ± 2.8 years) were exposed to four conditions prior to performing the Wingate Anaerobic Test: music-only, video and music, video with music and motivational primes, and a no-video/no-music control. Results indicate that the combined video, music, and primes condition was the most effective in terms of influencing participants' pre-task affect and subsequent anaerobic performance; this was followed by the music-only condition. The findings indicate the utility of such stimuli as a pre-performance technique to enhance athletes' or exercisers' psychological states.

There is a well-established literature demonstrating the influence of visual primes on decision-making processes and situational motivation. It has been proposed that human motivation can be activated automatically without the involvement of conscious guidance or choice (Bargh, 1990). Priming techniques pertain to temporary activation states and how the interaction of environmental information with internal readiness influences perceptions and evaluations as well as motivations and behaviors (Bargh, 1997). Research in social cognition has shown that individuals are largely unaware of the processes underlying their perceptions, goal pursuits, and behaviors (e.g., Levesque & Pelletier, 2003). Such processes are likely to play a vital role in human cognitions and behavior. An oft-used example of priming is that of the movie goer seeing an image of a soft drink can in a millisecond during a movie, which compels them to purchase that drink during the intermission (Vicary, 1957 cited in Radford, 2007). There have been only very few studies examining the influence of the priming phenomenon in relation to physical activity and motor tasks (e.g., Ashford & Jackson, 2010).

Music and video in sport and physical activity

Another type of stimulus that has been widely reported to bear an influence on people's motivation and psychological states, particularly in the domain of sport and physical activity, is music (e.g., Bood et al., 2013; Fritz et al., 2013; Sanchez, Moss, Twist, & Karageorghis, 2014). Athletes appear to routinely use music to enhance both motivational states and performance (e.g., Bishop et al., 2007; Harwood et al., 2011). Notwithstanding the fact that athletes often report positive effects of music during training and competition (e.g., Bishop et al., 2007; Laukka & Quick, 2013), scientific evidence to support such effects remains limited. Research to date that has examined the effects of music on athletic performance and psychological states has focused primarily on aerobic exercise (e.g., Waterhouse et al., 2010) with the majority of studies reporting positive effects (e.g., Karageorghis & Jones, 2014).

There is only limited empirical work into the effects of music on anaerobic performance (e.g., Yamamoto et al., 2003; Eliakim et al., 2007; Hutchinson et al., 2011; Fritz et al., 2013; Karageorghis et al., 2013). The results of these studies were equivocal with some reporting positive effects of music on performance (Eliakim et al., 2007; Hutchinson et al., 2011; Karageorghis et al., 2013), and others reporting no beneficial effects (e.g., Yamamoto et al., 2003; Fritz et al., 2013). Further, a few studies have examined either music or video as separate experimental stimuli (e.g., Scott et al., 1999; Nethery, 2002). Nethery (2002) reported that music was superior to video-only, a sensory deprivation condition, and control in terms of reducing RPE during a 15-min low-intensity (50% VO_{2peak}) exercise bout on a cycle ergometer.

Barwood et al. (2009) used a 15-min treadmill run during which they administered a condition that combined motivational music with motivational films (British sporting successes). This condition enabled participants to run further than control without a corresponding increase in RPE. The work was limited by a small sample size ($n = 6$) and the use of a climate chamber to induce heat stress. More recently, Hutchinson, Karageorghis, and Jones (2014) extended this line of work by examining a range of psychological variables in response to music and music-video at exercise intensities above and below ventilatory threshold. They reported that music-video elicited the highest levels of dissociation, lowest RPE, and most positive affective responses regardless of intensity.

Eliakim et al. (2007) investigated the effect of arousing music during warm-up for anaerobic performance (Wingate Anaerobic Test; WAnT) in adolescent volleyball players. Results indicated significantly higher peak anaerobic power following warm-up with music, but no differences in the mean power or fatigue index. Also, gender did not moderate the impact of the music. Eliakim et al. reported that the main effect of music occurred only during the initial phase of the exercise. This is consistent with the purported mechanisms at play in such pre-task applications of music that pertain to stimulation of the brain stem, the triggering of emotional associations, and the promotion of task-relevant imagery (e.g., Juslin, 2013).

The utility of heart rate variability (HRV)

In testing the combined influence of stimuli such as primes, video, and music, the collection of objective measures (e.g., HRV) alongside subjective ones (e.g., affect and exercise-induced feelings) confers a fuller understanding of such influence during aerobic and anaerobic exercise. Such measures also provide essential “clues” pertaining to the mechanisms that have been proposed to underlie the effects of pre-task music (Juslin, 2013). HRV is a noninvasive electrocardiographic marker that reflects the activity of the sympathetic and vagal components of the autonomic nervous system on the sinus node of the heart. It indicates the total amount of variations of both instantaneous heart rate (HR) and RR intervals (intervals between QRS complexes of normal sinus depolarizations (Sztajzel, 2004).

Berntson et al. (1997) suggested that measures of HRV could be particularly salient in the assessment of relationships between physiological and psychological processes. Moreover, Appelhans and Luecken (2006) argued that HRV is an accessible tool that can further understanding of emotional responses to environmental stimuli. They provided a theoretical and empirical basis for the application of HRV as an index of regulated emotional responses. Within the frequency domain, high frequencies are a result of parasympathetic nervous activity and associated with positive emotions; contrastingly, low frequencies are a result of sympathetic nervous activity and pertain to negative emotions.

Given that it is consistently reported that intense emotions can ensue as a result of listening to music (e.g., Juslin, 2013; Park et al., 2013), music could be used to induce particular emotions in experimental or clinical settings. A study comparing the effects of music and white noise on the recovery of physiological measures following stressful visual stimulation (Sokhadze, 2007), reported a significantly lower HF component of HRV when using both pleasant and sad music, in comparison to both visual stimulation and white noise. HRV is an established measure of mental workload within certain subfields of psychology (e.g., ergonomics) but has been seldom used in the realm of sport and physical activity.

Rationale, purpose, and hypotheses

It is noteworthy that no study has examined the effects of a video-music condition or the effects of priming conditions on all-out anaerobic performance. Also, the majority of studies, with the exception of two (Barwood et al., 2009; Hutchinson et al., 2014), examined the effects of music and/or video during exercise (e.g., Scott et al., 1999; Nethery, 2002). Accordingly, there is a need to examine the use of pre-task video, music, and priming conditions and their effects on anaerobic performance given the direct implications for sporting or exercise-related performance. In particular, athletes are no longer able to use electronic devices during competition and so the utility of stimuli such as video and music has been emphasized with reference to pre-event preparation (e.g., Eliakim et al., 2007).

The purpose of the present study was to examine the psychological and psychophysiological effects of priming, video, and music when used as a pre-performance intervention for an anaerobic endurance task. Psychological measures included the main axes of the circumplex model of affect (Russell, 1980), liking, and the four subscales of the Exercise-induced Feeling Inventory (EFI; Gauvin & Rejeski, 1993). Physiological measures comprised HRV components (high and low frequency) and HR, which were recorded prior to initiation of the WAnT. Four research hypotheses were tested: H_1 Experimental conditions would have significant positive effects on psychological measures when compared with control. H_2 Video with music and priming would yield the most positive effects on psychological measures. H_3 There would be a significant increase in performance in all experimental conditions when compared with control. H_4 There would be a significant increase in sympathetic activity (LF) and a significant decrease in parasympathetic activity (HF) during the pre-performance intervention phase of the experimental conditions when compared with control.

Method

Determination of sample size

Using power analysis software (G*Power 3; Faul et al., 2009), the mean effect size (*d*) 0.532 calculated using two meta-analyses of subliminal priming (Anatchkova & Rossi, 2002; DeCoster & Claypool, 2004), and a power of 0.80, a sample of 15 participants was needed to detect an effect in a repeated measures design.

Participants

Following procurement of institutional ethical approval, a convenience sample of 15 male volunteers (age = 26.3 ± 2.8 years) who were heterogeneous in terms of level of sports participation participated in the study. Seven of them were participating in sports at recreational level, three at club level, one at county level, one at regional level, one at national level, and two at international level. Participants' mean height was 177.9 ± 7.1 cm and their mean mass was 74.3 ± 12.9 kg.

Experimental conditions

Experimental conditions comprised video footage from past Olympic Games (5-min montage) coupled with either music and/or verbal primes. Vangelis's *Chariots of Fire* accompanied the video clips, given its strong association with the Olympic Games reinforced through the eponymous 1981 movie. Primes consisted of three words, *Push, Drive, Go*, that were deemed relevant to the anaerobic test. Experimental conditions included music-only, video and music, and video with motivational priming and music. There was also a control condition in which participants were not presented with any of the aforementioned stimuli. Ten British sport scientists (age = 35.4 ± 5.8 years) were asked to respond to a short questionnaire to provide words that might be used as primes. An explanation of the study was provided, as well as possible words to act as a guide.

Instrumentation

Affect

Participants were asked to state how they felt after listening to/watching the particular piece of music/video presented to them, in terms of pleasure and arousal (the two main axes of the circumplex model of affect [Russell, 1980]). Responses were provided on an 11-point Likert-type scale anchored by 0 (*not at all*) and 10 (*very much so*). Using the same scale, participants were also asked to rate how much they liked each condition.

Exercise-induced feelings

The EFI (Gauvin & Rejeski, 1993) was used to assess the feelings associated with an acute bout of physical activity. The EFI consists of 12 items quantifying four feeling states; namely, positive engagement (e.g., "happy"), revitalization (e.g., "refreshed"), tranquillity (e.g., "peaceful"), and physical exhaustion (e.g., "tired"). Participants rated their feelings using a 5-point Likert scale anchored by 0 (*do not feel*) and 4 (*feel very strongly*). Gauvin and Rejeski provided initial evidence for concurrent and discriminant validity of the EFI as well as satisfactory internal consistency reliability for all subscales (*M* alpha = 0.77). Further, Karageorghis et al. (2000) provided satisfactory alpha coefficients for all subscales, positive engagement = 0.72, revitalization = 0.77, tranquillity = 0.78, physical exhaustion = 0.81 in an exercise-to-music context.

Anaerobic performance

The WAnT was developed to assess muscle power, muscle endurance, and fatigability. It is also accepted as a reproducible, standardized task with which to analyze physiological and cognitive responses to supramaximal exercise (Inbar et al., 1996). The WAnT has been found to be valid and reliable in a range of previous studies (e.g., Thompson et al., 1986) and with anaerobic indices measured in the laboratory (e.g., Bar-Or et al., 1977) resulting in correlation coefficients over 0.75. Further, correlation coefficients of studies that examined test-retest reliability of the WAnT ranged from 0.89 to 0.99 (e.g., Bar-Or et al., 1977; Hebestreit et al., 1993).

Physiological measures

A PowerLab 16/30 (ADInstruments, Sydney, Australia) data acquisition system connected to an Octal BioAmp was used to perform a three-lead electrocardiogram (ECG) measurement. HRV frequencies [low frequency (LF) and high frequency (HF)] and HR were derived through spectral analysis of the ECG signal using Chart™ 5 Pro software v.5.5.1 (ADInstruments, Sydney, Australia). The spectral power in the frequency ranging between 0.04 Hz and 0.15 Hz was defined as LF while HF consisted of frequencies > 0.15 Hz. To filter the ECG signal, a low pass filter with a cutoff frequency of 100 Hz together with mains filtering was used. This served to remove the common 60 Hz mains frequency of noise caused by electricity in the laboratory.

Procedure

Each participant was habituated to the WAnT and then asked to visit the laboratory on a further four occasions. The visits took place at the same time of day and were separated by at least 1 day of rest. Elite sport participants were always tested the day after their rest day and before training. Participants were asked, both verbally and in writing, to refrain from any form of exercise on the day of testing before visiting the laboratory and from eating or drinking (except water) at least 2 h prior to the test.

Each participant provided written informed consent and some demographic details before completing the Physical Activity Readiness Questionnaire (The Canadian Society for Exercise Physiology, 2002). The experiment was explained and anthropometric measurements (height and mass) were taken before each participant was prepared for the ECG data acquisition. Once the ECG cables were in place, participants were asked to adopt an upright position on a Monark 894E cycle ergometer (Monark, Stockholm, Sweden). Immediately prior to the WAnT, a 5-min baseline HRV measure was obtained using ECG, followed by another 5-min HRV measure during which the participant was exposed to a visual and/or auditory condition through a 22 in. TFT LCD monitor (Prolite E2200WS, Iiyama Corporation, Tokyo, Japan) placed 1.5 m in front of them.

Participants were asked to sit in an upright position on the cycle ergometer and remain as stable as possible during the HRV acquisition phase. Sound intensity was adjusted to 75 dB (ear level) using a decibel sound meter (CR:303 Sound Level Meter, Cirrus Research Plc, Hunmanby, United Kingdom). Experimental conditions were administrated in a counterbalanced order and primes of 40 ms duration were presented randomly on the monitor. Following exposure to each condition, participants rated their affect and liking for the condition using the two main axes of the circumplex model. The WAnT was then performed, and immediately afterwards, the EFI was administered.

Anaerobic test procedure

Participants were instructed to cycle for 30 s against a constant resistance corresponding to 7.5% of their bodyweight (kg). Seat height and handlebars were adjusted according to the participant's build and stature. Following a warm-up period of 3 min at a constant pace of 50 RPM, participants were asked to decelerate and then accelerate in their own time in order to overcome inertia. Once they accelerated to 75 RPM the requisite resistance was applied automatically and the testing period initiated. Each participant was not exposed to any experimental stimuli during the WAnT; they were instructed to pedal as fast as possible and maintain maximal speed throughout. No verbal encouragement was given during the test and at the end, the resistance was removed and the participant continued pedaling for at least another 3 min in order to avoid feelings of dizziness and/or syncope.

For each test, the peak power output, mean power output, and minimum power output were calculated in Watts per kilogram of body weight (W/kg) by the WAnT computer software. The fatigue index for each individual was calculated using the equation (Inbar et al., 1996, p. 11):

$$\text{Fatigue index (FI)} = \frac{(\text{Peak power} - \text{Minimum power}) \times 100}{\text{Peak power}}$$

Statistical analysis

The dependent variables consisted of the four performance outcomes calculated using the WAnT computer software, affect measures, and exercise-induced feelings. Further, physiological dependent variables included HR and HRV. Data were screened using standardized scores ($-3.29 \leq z \geq 3.29$) for univariate outliers and Mahalanobis distance tests for multivariate outliers ($P < 0.001$; Tabachnick & Fidell, 2014), and tests for the relevant parametric assumptions were conducted. To ensure that participants' level of sport participation had no bearing on the dependent variables, a series of mixed-model condition × participation level multivariate analyses of variance (MANOVAs) were calculated. Thereafter, four single-factor repeated measures MANOVAs, one for affective responses, one for the EFI subscales, one for the HR/HRV measures, and one for the WAnT results, were conducted to examine differences among conditions.

Results

Outlier, normality, and level of sport participation checks

Data screening revealed no univariate or multivariate outliers. Tests for the distribution of data in each cell of the analysis revealed violations of normality in one of the four cells for the pleasure score ($P < 0.01$), one of the four cells for the liking score ($P < 0.001$), one of the four cells for positive engagement ($P < 0.01$), two of the four cells in HR ($P < 0.01$ and $P < 0.001$), and one of the four cells for the fatigue index score ($P < 0.01$; see Table 1). MANOVA and ANOVA are sufficiently robust to withstand the predominantly minor violations of normality described herein ($P < 0.01$; Keppel, 1991). Given that, overall, very few cells were identified as exhibiting significant skewness and kurtosis, it was decided not to distort the dataset through logarithmic transformation. Nonetheless, the liking score, HR data, and fatigue index should be interpreted with due caution. In all the MANOVAs, Mauchly's test of sphericity was violated; therefore, the *F*-tests were subjected to a Greenhouse–Geisser adjustment and Pillai's Trace was the omnibus statistic of choice.

A series of condition × participation level MANOVAs to ascertain whether participants' level of sport participation had any bearing on the dependent measures indicated no significant differences: affective measures, Pillai's Trace = 0.45, $F(18,108) = 1.07$, $P = 0.391$, $\eta_p^2 = 0.15$; exercise-induced feelings, Pillai's Trace = 0.53, $F(22,144) = 0.03$, $P = 0.565$, $\eta_p^2 = 0.13$; cardiac measures, Pillai's Trace = 0.43, $F(18,108) = 1.00$, $P = 0.461$, $\eta_p^2 = 0.14$; power-related indices, Pillai's Trace = 0.61, $F(24,144) = 1.09$, $P = 0.365$, $\eta_p^2 = 0.15$.

Analysis of affective measures

The main effect was significant, Pillai's Trace = 0.92, $F(9,6) = 7.43$, $P < 0.05$, $\eta_p^2 = 0.92$, indicating differences across experimental conditions. The effect size indicated that 92% of the variance could be accounted for by the independent variable manipulation. The follow-up univariate tests indicated that participants reported the highest scores for pleasure in the video-music-primes condition (7.33 ± 1.50) and the video-music condition (6.73 ± 1.22), followed by the music condition (6.47 ± 1.13), and control (5.13 ± 1.36) respectively (see Fig. 1). Follow-up pairwise comparisons with Bonferroni adjustment indicated significant differences between the video-music-primes and control conditions (95% CI 1.07–3.33, $P < 0.001$), as well as between the video-music-primes and music conditions (95% CI 0.03–1.71, $P < 0.05$). Further, significant differences were evident between the video-music and control conditions (95% CI 0.66–2.54, $P < 0.01$), as well as between the music condition and control (95% CI 0.62–2.05, $P < 0.001$).

Similar observations were revealed for the arousal axis with participants reporting the highest scores for arousal in the video-music-primes condition (7.27 ± 1.58), followed by the video-music condition (6.73 ± 1.49), the music condition (5.87 ± 1.92), and control (4.33 ± 2.53; see Fig. 1). More specifically, the video-music-primes condition was significantly different to control (95% CI 1.28–4.59, $P < 0.01$) and the music condition (95% CI 0.25–2.55, $P < 0.05$). Finally, the video-music condition was significantly different to control (95% CI 0.85–3.95, $P < 0.01$).

As illustrated in Fig. 1, the most liked condition was video-music-primes (7.53 ± 1.30) followed by video-music (7.33 ± 0.90), music (6.33 ± 0.96), and finally, control (4.67 ± 1.35). Follow-up pairwise comparisons indicated that the video-music-primes condition was significantly more liked than the music condition (95% CI

Table 1. Descriptive and univariate statistics for all dependent variables

Dependent variable	Condition	M	SD	Std. Skew.	Std. Kurt.
Pleasure score	Control	5.13	1.36	1.24	0.11
	Music	6.47	1.13	−0.73	0.23
	Video-music	6.73	1.22	1.94	2.59*
	Video-music-primes	7.33	1.50	0.90	−0.39
$F(3,42) = 21.84$, $P < 0.001$, $\eta_p^2 = 0.61$					
Arousal score	Control	4.33	2.53	0.89	−0.23
	Music	5.87	1.92	−0.11	1.09
	Video-music	6.73	1.48	0.91	0.84
	Video-music-primes	7.27	1.58	−1.74	3.07
$F(1.701, 31.571) = 43.45$, $P < 0.001$, $\eta_p^2 = 0.54$					
Liking score	Control	4.67	1.35	0.17	0.28
	Music	6.33	0.98	0.48	−0.58
	Video-music	7.33	0.90	3.34**	4.78**
	Video-music-primes	7.53	1.30	−0.14	0.02
$F(1.1668, 23.352) = 26.49$, $P < 0.001$, $\eta_p^2 = 0.65$					
Positive engagement	Control	9.73	2.12	−3.24*	3.03*
	Music	9.40	1.55	0.26	−0.42
	Video-music	10.13	1.19	−0.50	0.04
	Video-music-primes	10.80	1.57	0.43	0.15
$F(1.511, 21.154) = 4.05$, $P < 0.05$, $\eta_p^2 = 0.22$					
Revitalization	Control	8.27	1.83	0.05	−0.84
	Music	8.40	1.99	−0.35	−1.28
	Video-music	8.73	1.91	−1.33	1.59
	Video-music-primes	9.67	2.55	0.38	0.08
$F(3, 42) = 2.90$, $P > 0.05$, $\eta_p^2 = 0.17$					
Tranquillity	Control	8.40	2.29	0.72	−0.71
	Music	7.93	1.87	0.45	0.34
	Video-music	8.53	2.47	0.01	−0.25
	Video-music-primes	8.67	2.82	−0.73	−0.21
$F(3, 42) = 0.532$, $P > 0.05$, $\eta_p^2 = 0.04$					
Physical exhaustion	Control	8.60	2.03	0.68	−0.74
	Music	9.33	2.66	−0.04	−0.88
	Video-music	8.73	1.98	0.95	−0.97
	Video-music-primes	9.20	2.08	0.14	−0.82
$F(3, 42) = 1.89$, $P > 0.05$, $\eta_p^2 = 0.05$					
Heart rate	Control	3.98	8.09	1.47	−0.30
	Music	−3.98	4.04	−2.72*	3.65**
	Video-music	−1.36	3.87	2.97*	3.36**
	Video-music-primes	−3.37	3.78	−1.06	1.83
$F(3, 42) = 6.50$, $P < 0.01$, $\eta_p^2 = 0.32$					
Low frequency	Control	0.83	14.61	−1.88	0.38
	Music	−7.97	10.74	0.28	−0.55
	Video-music	−11.42	7.17	1.40	−0.26
	Video-music-primes	−9.98	13.66	−0.78	−0.62
$F(3, 42) = 4.39$, $P < 0.01$, $\eta_p^2 = 0.24$					
High frequency	Control	−1.34	14.40	1.73	0.20
	Music	8.50	10.58	−0.42	−0.39
	Video-music	10.94	6.99	−1.28	−0.38
	Video-music-primes	9.75	14.15	0.67	−0.51
$F(2.101, 29.416) = 34.20$, $P < 0.05$, $\eta_p^2 = 0.23$					
Peak power	Control	10.81	1.30	−0.64	−0.81
	Music	11.03	1.46	0.64	−0.58
	Video-music	10.81	1.49	0.01	−0.87
	Video-music-primes	11.73	1.57	0.24	−0.60
$F(3, 42) = 4.99$, $P < 0.01$, $\eta_p^2 = 0.26$					
Mean power	Control	7.40	0.52	0.06	−0.95
	Music	7.38	0.58	0.34	−1.18
	Video-music	7.33	0.63	0.08	−0.65
	Video-music-primes	7.60	0.59	−0.20	−0.72
$F(3, 42) = 5.703$, $P < 0.01$, $\eta_p^2 = 0.29$					
Minimum power	Control	4.42	0.76	−0.03	1.92
	Music	4.30	0.77	−0.54	−0.84
	Video-music	4.43	0.61	0.24	−0.27
	Video-music-primes	4.81	0.59	−0.12	0.30
$F(1.912, 26.766) = 2.856$, $P > 0.05$, $\eta_p^2 = 0.03$					
Fatigue index	Control	58.78	7.73	−0.15	−1.08
	Music	60.62	7.34	0.05	−0.58
	Video-music	58.72	5.44	−0.51	−0.67
	Video-music-primes	58.49	7.06	−2.78*	3.48**
$F(3, 42) = 0.48$, $P > 0.05$, $\eta_p^2 = 0.03$					

*$P < 0.01$, **$P < 0.001$.

Std. Skew., standard skewness; Std. Kurt., standard kurtosis.

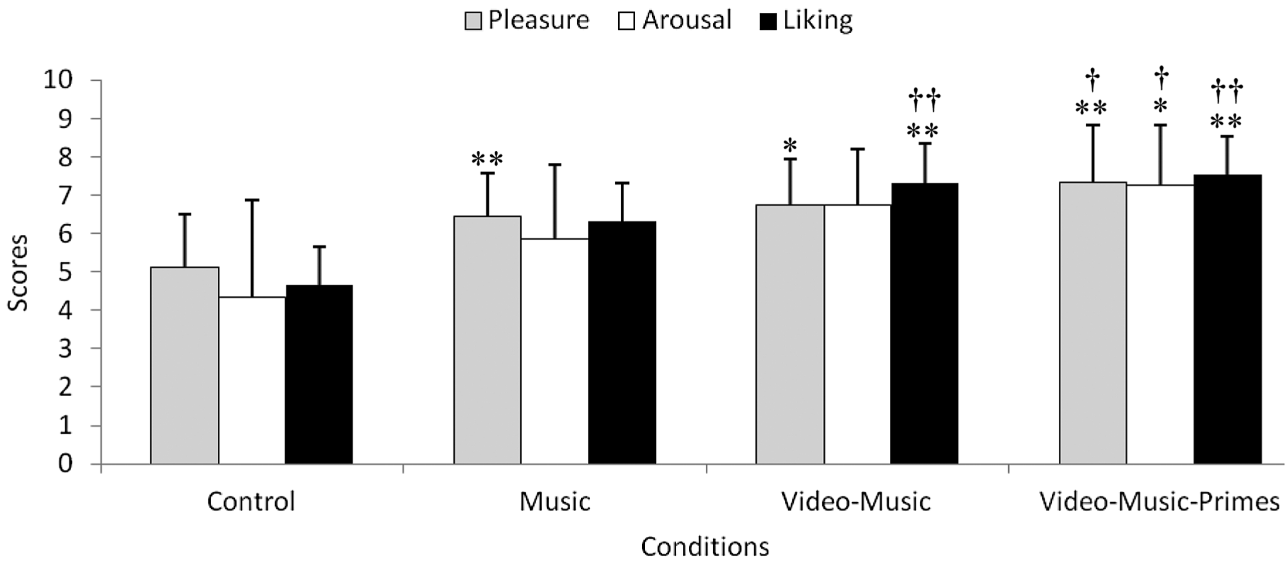

Fig. 1. Pleasure, arousal, and liking score changes across experimental and control conditions.
*Significantly different from the control for the corresponding score, $P < 0.01$.
**Significantly different from the control for the corresponding score, $P < 0.001$.
†Significantly different from the music condition for the corresponding score, $P < 0.05$.
††Significantly different from the music condition for the corresponding score, $P < 0.001$.

0.40–2.00, $P < 0.01$) and control (95% CI 1.37–4.36, $P < 0.001$). Further, the video-music condition was significantly more liked than control (95% CI 1.24–4.09, $P < 0.001$) and the music condition (95% CI 0.48–1.52, $P < 0.001$). Finally, the music condition was significantly more liked when compared with control (95% CI 0.41–2.93, $P < 0.01$).

Analysis of the EFI subscales scores

There was no significant effect, Pillai's Trace = 0.96, $F(12,3) = 5.55$, $P > 0.05$, $\eta_p^2 = 0.96$, indicating no differences among conditions. However, the effect size indicated that 96% of the variance was accounted for by the independent variable manipulation. This large effect prompted us to conduct follow-up tests to examine possible differences within the EFI subscales. Follow-up pairwise comparisons indicated significant differences in the positive engagement subscale for the video-music-primes condition (10.80 ± 1.57) when compared with the music condition (9.40 ± 1.55, 95% CI 0.68–2.12, $P < 0.001$). There was also a significant difference between the video-music (10.13 ± 1.89) and music conditions (95% CI 0.10–1.37, $P < 0.05$).

Analysis of the HRV data

There was no significant effect, Pillai's Trace = 0.77, $F(9, 6) = 2.24$, $P = 0.17$, $\eta_p^2 = 0.77$, indicating no differences among conditions. The effect size, however, indicated that 77% of the variance was accounted for by the independent variable manipulation. This large percentage of explained variance prompted us to conduct follow-up tests to examine possible differences. Pairwise comparisons indicated significant differences in HR between the control (3.98 ± 8.09) and video-music-primes conditions (–3.37 ± 3.79; 95% CI 0.16–14.54, $P < 0.05$). Further, a significant difference between the control (0.83 ± 14.61) and video-music conditions (–11.43 ± 7.18; 95% CI 1.41–23.10, $P < 0.05$) was observed in the low frequency component. A similar significant difference between the control (–1.34 ± 14.40) and video-music conditions (10.94 ± 6.99; 95% CI –23.22—1.36, $P < 0.05$) was observed in the high frequency component. In general, there was an increase in low frequency and decrease in high frequency in the experimental conditions, while the converse was evident in the control condition (see Fig. 2). In terms of HR, there was a decrease in the control condition and an increase in each of the experimental conditions (see Fig. 3).

Analysis of the WAnT results

There was no significant effect, Pillai's Trace = 0.84, $F(12,3) = 1.29$, $P > 0.05$, $\eta_p^2 = 0.84$; however, the effect size indicated that 84% of the variance was accounted for by the independent variable manipulation. This large percentage of explained variance prompted us to conduct follow-up univariate tests to examine possible differences. Follow-up univariate tests indicated significant differences between conditions in the peak power output and mean power output (see Fig. 4). Follow-up pairwise comparisons indicated significant differences in the peak power of the video-music-primes condition (11.73 ± 1.57) when compared with control (10.81 ± 1.30; 95%

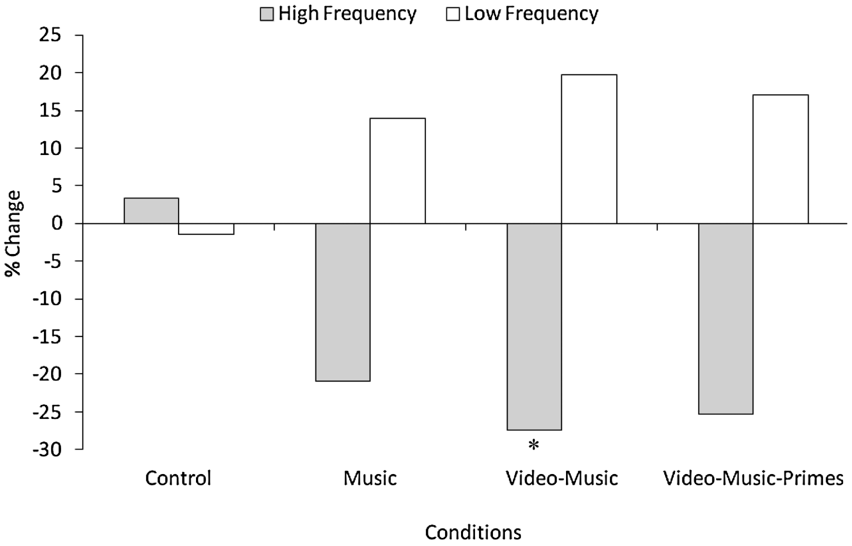

Fig. 2. Percentage changes in HRV high and low frequencies across experimental and control conditions. *Significantly different from control, $P < 0.05$.

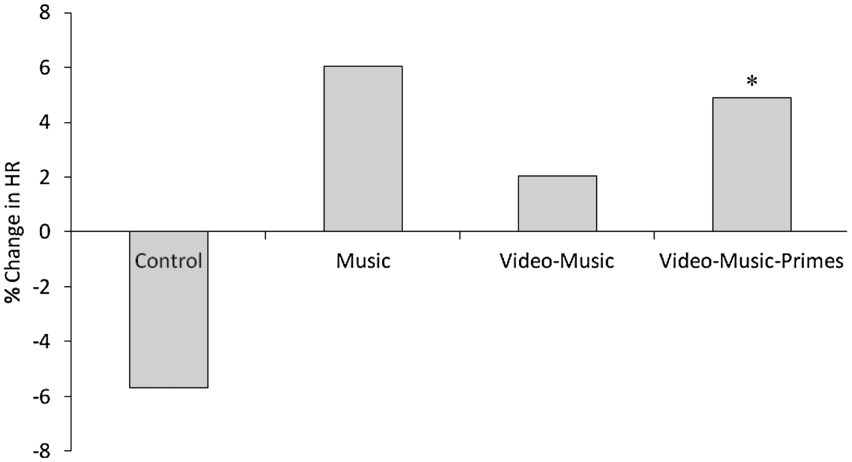

Fig. 3. Percentage changes in heart rate across experimental and control conditions. *Significantly different from control, $P < 0.05$.

CI 0.10–1.74, $P < 0.05$) and video-music conditions (10.81 ± 1.49; 95% CI 0.02–1.82, $P < 0.05$). In terms of mean power, significant differences were observed between the video-music-primes (7.60 ± 0.59) and music conditions (7.38 ± 0.58; 95% CI 0.01–0.43, $P < 0.05$), as well as between the video-music-primes and video-music conditions (7.33 ± 0.63; 95% CI 0.03–0.52, $P < 0.05$). Finally, no significant ($P > 0.05$) differences were observed among any of the conditions in terms of the minimum power output or fatigue index.

In summary, the results indicated that all experimental conditions were effective in terms of eliciting positive affective changes, with the video-music-primes condition being the most efficacious. In terms of the physiological measure of HRV, a general increase in low frequency with a corresponding decrease in high frequency during the experimental conditions was observed. Finally, the video-music-primes condition was the most effective in terms of enhancing anaerobic performance.

Discussion

The primary aim of this study was to investigate the effects of video, priming, and music on affective states and physiological measures prior to a supramaximal anaerobic test, and their subsequent impact on motor performance. Affective changes during the experimental conditions were assessed using liking, pleasure, and arousal scores. A secondary aim was to assess exercise-induced feelings on completion of the test.

The present results provided only partial support for the experimental hypotheses (H_1–H_4). All experimental conditions elicited significantly ($P < 0.01$) higher scores

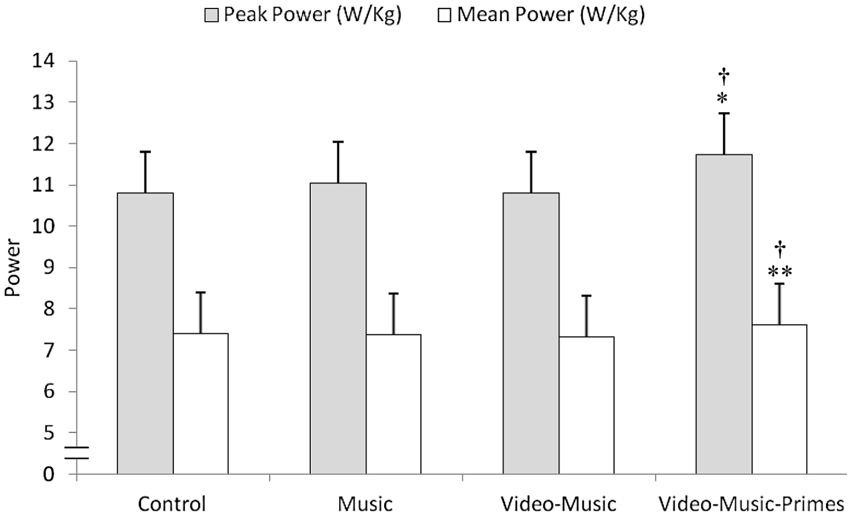

Fig. 4. Changes in peak and mean power (W/kg) across experimental and control conditions.
*Significantly different from the control, $P < 0.05$.
**Significantly different from the music condition, $P < 0.05$.
†Significantly different from the video-music condition, $P < 0.05$.

in terms of liking, arousal, and pleasure in partial support of H_1. However, significant differences were not observed in the exercise-induced feelings subscales, with the exception of positive engagement, wherein the video-music and the video-music-primes conditions yielded significantly ($P < 0.05$) higher scores when compared with the music condition. The video with music and primes condition was found to be the most influential for pre-task affective states and exercise-induced feelings in support of H_2. Further, there was a significant ($P < 0.05$) effect of condition on anaerobic performance wherein watching video with music and primes led to higher mean and peak powers (W/kg) compared with the remaining conditions; this did not support H_3, which stated that all experimental conditions would elevate performance relative to control. Video, music, and primes were associated with an increase in sympathetic (LF) activity and a decrease in parasympathetic (HF) activity prior to the WAnT (see Fig. 2). This change, however, only reached significance ($P < 0.05$) for the comparison between the video-music condition and control, which means that H_4 is not supported.

Affective responses

Arousal and pleasure scores exhibited a similar trend across conditions to that of ratings for liking (see Fig. 1). This indicated a possible association between the liking scores and scores derived from the main axes of the circumplex model of affect, supporting the proposition that the emotional responses to a musical piece can be predicted by the degree of preference that the listener holds, as well as by the degree of pleasure and arousal felt (e.g., North & Hargreaves, 1997). The positive outcomes associated with the video-music-primes condition (see Table 1 and Fig. 1) support the notion that priming can function as a tool to unconsciously alter an individual's psychological state prior to a task (Bargh, 1990). Akin to this, music has been suggested to enhance pre-task psychological states and affect (e.g., Bishop et al., 2007; Eliakim et al., 2007). Further, video could be used in psychological interventions for behavior modification and the regulation of psychological states (e.g., Templin & Vernacchia, 1995; Scott et al., 1999; Hutchinson et al., 2014).

Starting from the control condition and moving to the video-music-primes condition, an incremental increase in all three scales, liking, arousal, and pleasure, was observed (see Fig. 1). This suggests that each experimental stimulus had an additive effect when combined with other experimental stimuli, leading to the support of H_2, stating that the video-music-primes condition would be the most influential in terms of eliciting affective changes. Given that priming techniques are concerned with temporary activation states and internal readiness (Bargh, 1997), it appears that video, music, and primes provided a means by which to activate psychological states and internal readiness.

Exercise-induced feeling states

In terms of exercise-induced feelings, the video-music-primes, and the video-music condition scores were significantly ($P < 0.05$) higher in the positive engagement subscale of the EFI when compared with the music condition. Despite that fact that the effectiveness of external stimuli such as music is lessened by the physiological signals associated with high-intensity physical activity (e.g., Nethery, 2002; Eliakim et al., 2007), it does appear that two of the experimental conditions had a positive influence on how participants felt immediately after the supramaximal task. It is plausible that the video combined with music triggered extramusical associations related to striving for sporting glory and overcoming adversity, as depicted in the inspiring images of Olympic competition and the iconic cues of Vangelis's *Chariots of Fire*. Such iconic cues concern how structural elements of a musical work relate to the tone of certain emotions; for example, the synthesized brass sounds that grow in intensity during the introduction of *Chariots of Fire* may sound "rousing" because there are commonalities with rising energy levels and mounting anticipation (see North & Hargreaves, 2008). Given that such cues are grounded in the structure of music, the same music *should* hold similar "iconic meaning" for different people.

Effects on HRV

The HRV results indicated that it was only the video-music condition that yielded significant ($P < 0.05$) differences (see Fig. 2). Further, there were no significant changes observed in HR with the exception of a marginally significant ($P = 0.041$) change in the video-music-primes condition compared with control. These results, in combination with the affective changes observed, support the notion that HRV changes are reflective of physiological and psychological readiness to execute a particular task; the video-music condition yielded the most positive objective results, although only slightly superior to music-only and video-music-primes conditions (see Fig. 2).

In relation to the shifts from high to low frequency observed in the three experimental conditions (see Fig. 2), it is interesting to note that Iellamo et al. (2002) reported a similar shift from parasympathetic activity (HF) to sympathetic activity (LF) in high-performance athletes working at very high intensities. Their results suggest that the enhanced sympathetic activation (LF) together with a decrease in parasympathetic activity (HF) could reflect a neurophysiological adaptation that characterizes high-performance athletes. Further investigation of these phenomena causes is warranted given that the collection of objective measures (e.g., HRV) alongside subjective ones (e.g., affect, arousal, and liking) confers a fuller understanding of the influence of multiple pre-task stimuli on anaerobic performance.

Changes in anaerobic exercise performance

The video-music-primes condition was associated with a significant ($P < 0.05$) increase in peak anaerobic power when compared with the video-music and control conditions, as well as with a significant increase ($P < 0.05$) in the mean power output when compared with the music and video-music conditions (see Fig. 4). No significant differences were observed for the minimum power output or the fatigue index (see Table 1). The present results are in line with those of Yamamoto et al. (2003) who showed that listening to either fast or slow music pre-task had no impact on anaerobic performance. The findings were also not supportive of those of Eliakim et al. (2007) who associated arousing music during warm-up with increases in peak power output among volleyball players.

Conversely, the results of the current study demonstrate that when music was coupled with video and primes, a beneficial effect on the peak ($P < 0.05$) and mean ($P < 0.05$) anaerobic power output ensued (see Fig. 4). The significant increase with the mean power output in combination with the higher minimum power output and fatigue index during the video-music-primes condition, indicated that the effect of the video-music-primes condition did not only exist in the first moments of exercise (peak power output) but carried over to influence performance of the anaerobic task. This would suggest that beyond the brain stem reflex that was advocated as a salient mechanism (Juslin, 2013), the three words used as primes had a direct influence on power output by motivating participants to work harder.

Limitations of the present study

One of the main limitations that may have impacted on the results of the present study was the heterogeneous nature of the sample. Given the novelty of the study, we selected a heterogeneous group of athletes in order to maximize the generalizability of the findings but concede that the stimuli employed in the experimental conditions could have engendered subtly different effects across the levels of sport participation (cf. Iellamo et al., 2002). A further limitation entailed a lack of ecological validity (Harris, 2008), despite the fact that the WAnT yielded correlation coefficients larger than 0.75 when compared with anaerobic performance in the field (e.g., Thompson et al., 1986). A field-based anaerobic test could not be administered because of the lack of portable, wireless, and reliable equipment. Also, the need to establish stationarity (Berntson et al., 1997) and the sensitivity of the equipment used for HRV data acquisition (PowerLab 16/30, ADInstruments, Sydney, Australia) meant that data collection needed to take place in a controlled laboratory environment.

Although the EFI (Gauvin & Rejeski, 1993) was designed to assess feelings associated with acute bouts of physical activity, the use of a short and exhausting task, such as the WAnT, resulted in no significant variability in physical exhaustion, revitalization, and tranquillity subscales across conditions, thus probably obscuring the impact of video, music, and priming. The multivariate effect was nonsignificant despite 84% of the variance being accounted for by the independent variable manipulation. Moreover, the EFI has been subjected to some criticism in the literature in regard to its theoretical underpinnings and the rigor with which its content validity was established (Ekkekakis &

Petruzzello, 2001, 2003). Gauvin and Rejeski (2001) issued an ardent defense of the instrument based partly on the relative simplicity of the circumplex model of affect that was advocated by Ekkekakis and Petruzzello (2001, 2003), the strong psychometric properties of the EFI (see, e.g., Karageorghis et al., 2000), and its extensive use by exercise psychology researchers.

The tempo of the musical selection used might have influenced the psychological responses of the participants, given the implications of theoretical propositions that during physical activity, a preference toward fast tempo might prevail (e.g., LeBlanc, 1995; North & Hargreaves, 2008). However, the particular musical excerpt used clearly demonstrates strong musicality, cultural impact, and association; other factors that contribute to the motivational qualities of a piece of music (see Karageorghis et al., 1999).

Conclusions and Recommendations

The present study indicated that a combination of video, primes, and music could be used as a pre-performance technique to enhance participants' affective states prior to an anaerobic exercise task. Further, the effect of video, priming, and music prior to performance appeared to have a carryover effect influencing the level of anaerobic performance and enhancing participants' perception of post-task positive engagement. There is considerable scope to extend this line of investigation to more homogeneous samples than that employed in the present study, and in particular to elite sport samples where the benefits associated with video, priming, and music are likely to have a meaningful influence on performance. There is also scope for extension to other contexts such as public health and physical education.

Berntson et al. (1997) suggested that HRV measures could be used for the clarification of relationships between psychological and physiological processes. Previous studies in the area of HRV, emotions, and music (e.g., Sokhadze, 2007) yielded equivocal results. Our findings showed some correspondence between HRV components and affective scores, although the trends identified across conditions were not identical (see Table 1, Fig. 1 and Fig. 3). The present study showed sizeable improvements in the peak and mean powers, produced during the WAnT in the video-music-primes condition. Such results indicate the positive effects that priming techniques can have when used in tandem with psychological interventions (Bargh, 1990, 1997; Ashford & Jackson, 2010).

Further work in the area of psychophysiology should seek to examine the effects of video, priming, and music techniques in conjunction with other indices of cardiovascular functioning (Task Force, 1996) as well as employing electroencephalography EEG and functional magnetic resonance imaging fMRI techniques in order to clarify the exact mechanisms responsible for the potential role of video, priming, and music in eliciting the observed psychological and physiological responses. Future work could include the investigation of video, priming, and music techniques in long duration, aerobic-type activities. Beyond the realm of sport, the effects of such techniques on psychological states and HRV during exercise, post-exercise during the recovery phase, and in injury rehabilitation programs might also be investigated.

Perspectives

The interactive effects of video, priming, and music have not been investigated in the domain of sport and physical activity despite the fact that many studies have investigated music in isolation (e.g., Eliakim et al., 2007; Bood et al., 2013; Sanchez et al., 2014), while a small number have investigated music and video in combination (e.g., Barwood et al., 2009; Hutchinson et al., 2014). The present study sought to combine subjective (affect, arousal, liking) and objective (HR, HRV) measures in assessing the efficacy of video, primes, and music used prior to performance of the WAnT. The findings showed that it was generally a video-primes-music condition that yielded the most positive results across the gamut of dependent measures. The main contribution of this work has been the identification of links between video, priming, music, and concomitant changes in both emotion and HRV during experimental exposure to such conditions.

Key words: Automatic activation, motivational videos, sympathetic activity, psychophysiology.

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