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Prime Movers: Effects of Subliminal Primes, Music, and Music-Video on Psychological Responses to Exercise

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Abstract

Background Priming is a process in which exposure to a stimulus activates relevant mental representations that are given increased weight in subsequent judgment tasks. Affective primes can influence affective evaluations and associations. Such influence has meaningful implications for the promotion of exercise behavior, yet there is scant research on priming effects in exercise settings.

Purpose The purpose of the present pair of studies was to examine the efficacy of music (M), music-video (MV), and music-video with affective primes (PRIME) in modulating psychological responses during and immediately following an exercise bout among two distinct populations.

Methods In Study 1, physically active participants completed a brisk walking task on a treadmill under four conditions: M, MV, PRIME, and control. Affective valence and rating of perceived exertion (RPE) were assessed during exercise and remembered/forecasted pleasure were measured immediately following each exercise bout. In Study 2, largely inactive and overweight participants completed a brisk walking task on a treadmill under two conditions: MV and PRIME. Affective valence was assessed during exercise while exercise enjoyment and remembered/forecasted pleasure were assessed postexercise.

Results In Study 1, PRIME yielded more positively valenced affect, remembered/forecasted pleasure, and lower RPE when compared to the other conditions ($M_{\text{Cohen's } d}$ for all DVs = 0.91). In Study 2, PRIME elicited more positively valenced affect, greater enjoyment, and enhanced remembered/forecasted pleasure when compared to MV ($M_{\text{Cohen's } d}$ for all DVs = 0.64).

Conclusions Subliminal primes embedded in music-video can elicit positive changes in psychological responses during and immediately following exercise.

Keywords Affective response, dissociation, perceived exertion, subliminal priming

Introduction

The physical and psychological benefits of exercise and physical activity are well established, yet most people in industrialized countries are sedentary or insufficiently active [1]. Finding effective ways to increase physical activity and exercise participation is an ongoing and compelling challenge for the field of behavioral medicine. Based upon the motivational principle that people have a tendency to approach pleasure and avoid pain, *hedonic theory* [2] provides a useful framework with which to understand exercise-related behaviors.

The underlying premise of the application of hedonic theory to exercise concerns how an individual feels both during and after exercise. This has a direct bearing upon their likelihood to repeat that experience in the future [3]. Negative feelings during exercise are strongly associated with a decrease in motivation to continue exercising, while positive feelings are associated with continued exercise participation [4]. In line with the predictions of hedonic theory, research has established a positive association between acute affective responses to exercise and future participation [5, 6]. In addition, the role of remembered pleasure (how pleasant or unpleasant an event is remembered) and forecasted pleasure (how pleasant or unpleasant future bouts are expected to be) has emerged as a salient factor in determining future exercise behavior [7].

Research into the exercise intensity–affective response relationship has found that exercise intensities below the ventilatory threshold (VT) are associated with more positively valenced affect compared to intensities that exceed VT [8]. One explanation for this is exercisers' more effective use of dissociation strategies during exercise at intensities below VT [9]. A variety of dissociation strategies have been found to be efficacious in enhancing affect during exercise, including music and music-video [10, 11], mobile applications [12], directed focus toward positive outcomes [13], and virtual reality [14]. One method of increasing positive feeling states that has not been examined in an exercise context is *subliminal priming*. Priming refers to the

passive, subtle, and unobtrusive activation of relevant mental representations by external stimuli, without a person being consciously aware of the influence exerted by such stimuli [15]. Priming manipulations can be either *subliminal* or *supraliminal*. In the case of supraliminal priming, individuals are aware of an environmental cue, but are not aware of its influence on them [16]. Subliminal primes, which are the focus of the present pair of studies, are presented below the threshold of conscious awareness, and are typically masked in some way in order to reduce or eliminate conscious perception [17].

Research on interventions that target nonconscious processes is scant. Nonetheless, priming has been studied in the context of *implicit attitudes*; the automatic affective responses forged through particular associations with a given stimulus [18]. Implicit attitudes play a critical role in regulating physical activity and this role is distinct from the influence of more reflective processes [19]. These attitudes can be modified through a process known as *evaluative conditioning*; this occurs when the valence of a stimulus is changed due to pairing it with another stimulus that can be either positive or negative [20]. A small body of work has emerged concerning the impact of priming interventions on health-related behaviors. Blanchfield, Hardy, and Marcora [21] assessed the effect of priming on rating of perceived exertion (RPE) and time to exhaustion during a cycling task. Participants were primed with either happy or sad faces during a visual vigilance task. Time to exhaustion was 12% longer and RPE significantly lower in the happy face compared to the sad face condition.

Loizou, Karageorghis, and Bishop [22] demonstrated the efficacy of motivational words embedded into video-with-music to positively influence emotional states and the psychological needs that underlie intrinsic motivation. Subsequently, Loizou and Karageorghis [23] examined both the singular and interactive effects of pre-task video, music, and priming conditions on

affective state and anaerobic performance among male athletes. The motivational primes were *Push, Drive,* and *Go* – words that the authors deemed relevant to the anaerobic test. The combined video, music, and primes condition was the most effective in terms of optimizing participants' pretask affect (valence and arousal) and subsequent anaerobic performance. The authors concluded that music-video with primes provided an effective means by which to activate psychological states and internal readiness prior to an anaerobic exercise task. They suggested that future research should examine priming effects in more diverse populations, during longer aerobic exercise tasks, and at different time points (i.e., during and after exercise).

Study 1

The purpose of Study 1 was to investigate the effects of positively valenced affective primes embedded in music-videos on affective valence and RPE during exercise, and on remembered pleasure and forecasted pleasure immediately following exercise. The study employed a within-subjects design that required participants to complete a brisk walking task under four conditions: music (M), music-video (MV), music-video with subliminal primes (PRIME), and control. It was hypothesized that the PRIME condition would lead to more positive in-task affective valence and lower RPE, coupled with higher remembered and forecasted pleasure when compared to M, MV, and control conditions.

Method

Power Analysis. A power analysis using G*Power software [24] was conducted for a 4 (condition) × 4 (time) RM ANOVA for in-task affective valence based on a predicted medium effect size ($f = 0.25$) [10], an alpha level of .05, and power of 0.8. This indicated that a minimum of 24 participants would be required. An extra four participants were recruited to protect against attrition and deletions due to outliers.

Participants. Volunteer females (N = 28) were recruited from a New England college by use of convenience sampling. Study participants exhibited the following characteristics: age, M = 22.6 years, SD = 3.3 (range: 18–30); BMI, M = 23.9 kg/m^2, SD = 4.1 (range: 19.2–36.6); body fat, M = 28.3%, SD = 8.5 (range: 17.6–50.2); race, White = 86%, Asian = 3%, other = 11%. The majority (86%) of participants were physically active in accord with ACSM guidelines (> 150 min of moderate-intensity exercise/week) [25].

Stimuli and Measures. The audiovisual stimuli were selected using criteria pertaining to motivational music (> 120 beats per minute [bpm]) outlined by Karageorghis and Terry [26] and criteria for motivational music-videos presented by Hutchinson et al. [10]. A focus group of female students at a New England college rated a series of music-videos on the salient facets of rhythm, style, melody, tempo, instrumentation, and beat using the Brunel Music Rating Inventory-2 (BMRI-2) [27], a validated instrument designed to assess the motivational qualities of music in an exercise context. The affective qualities of the music videos were rated by use of the Affect Grid [28]. The two tracks used in the experimental conditions were *Good Feeling* by Flo Rida (129 bpm) and *I Can Only Imagine* by David Guetta feat. Chris Brown and Lil Wayne (128 bpm). These tracks elicited BMRI-2 scores of 30–32 (out of a possible 42), which are indicative of strong motivational qualities in the exercise context [27] and ratings in the upper-right quadrant of the Affect Grid; associated with positive valence and high arousal.

Affective primes consisting of positively valenced words (happy, pleased, joyful) were embedded into the music-videos for the PRIME condition. These words were selected in accord with their high valence ratings with reference to the Affective Norms for English Words database [29]. Each word appeared on the screen for 16 ms during the music-video, which is below the threshold for conscious perception [30]. Given that repeated exposures to primes lead to

stronger and longer lasting effects [31], embedded words appeared every 10 s throughout the music-video. To prevent possible habituation to the positive words [32], two-thirds of the words were neutral (table, pencil, tree), and one-third comprised the positively valenced words.

In-task affective valence was assessed by use of the Feeling Scale (FS) [33]; a single-item scale that measures how an individual feels during exercise with possible responses ranging from -5 (*very bad*) to +5 (*very good*). RPE was measured by use of Borg's CR-10 Scale [34], which ranges from 0 (*nothing at all*) to 10 (*extremely strong*). Remembered pleasure was measured using a 200-mm visual analog scale (VAS). Respondents were administered the item, "How did the exercise session make you feel?", with responses ranging from -100 (*very unpleasant*) to +100 (*very pleasant*). Participants drew a line through the point along the scale that best represented how they felt during the exercise bout; a ruler was used to determine the exact score. Finally, forecasted pleasure was assessed by use of the single-item Empirical Valence Scale (EVS) [35]. The EVS has empirically spaced verbal descriptors along a continuous visual analogue-scale ranging from -100 (*most unpleasant imaginable*) to +100 (*most pleasant imaginable*) [35]. Participants were asked "If you repeated the exercise session again, how do you think it would make you feel?" and marked their response on the EVS. Forecasted and remembered pleasure were assessed using a different scale to those used in-task (i.e., the FS) in order to minimize common method variance [36].

Procedure. Approval from the Institutional Review Board of the second author was received and all participants provided written informed consent. Participants were asked to refrain from high-intensity exercise for 24 hr prior to each session. At the first session, participants' body mass (kg) and body composition were assessed using bioelectrical impedance (Tanita BC 418). A pretest to establish participants' maximum heart rate (HRmax) was then

administered using the Bruce Treadmill Protocol [37]. Participants were asked to rate affective valence and RPE every 2 min using the FS and Borg CR-10 Scale, respectively. This served as a form of scale familiarization prior to experimental conditions. Heart rate (HR) was monitored and recorded throughout the test using a HR monitor (Polar Electro Inc.).

On completion of the pretest, there was a 20-min recovery period followed by a habituation session. The Karvonen formula [38] was used to calculate exercise HR for 65% heart rate reserve (HRR) based upon the HRmax recorded in the pretest. This intensity was chosen to test the novel priming intervention, as it approximates the intensity at which dissociative strategies work most effectively to influence affective response [39, 40]. For the habituation protocol, participants walked on a treadmill that gradually increased in velocity, in order to establish the velocity associated with their 65% HRR. The speed at which HR stabilized at 65% HRR for 2 min was the velocity used during the experimental phase.

Participants returned 48 hr later and were administered four experimental conditions: Music (M), music-video (MV), music-video with primes (PRIME), and control (no music, video, or priming). Audiovisual stimuli were delivered using a 13″ tablet (HP Split x2, HP Inc.) positioned on the treadmill console, with the tablet speaker set at a standardized sound intensity of 75 dBA. To counter any potential order effects, a Williams' square was used to randomly assign condition order. Each condition consisted of an 8-min brisk walking task during which affective valence and RPE were measured at Minutes 2, 4, 6, and 8. Following each bout of exercise, the VAS and EVS were used to assess remembered and forecasted pleasure, respectively. Participants were then afforded a 5-min break during which a simple mental arithmetic task was administered as a "filler" to mitigate any potential carryover effects [41]. This protocol was repeated under a different condition until all four conditions had been

completed. Thereafter, a funneled debriefing procedure [15] was used to assess whether participants were aware of the affective primes. If any participant correctly identified the purpose of the study or mentioned the primes, her data would not have been included for analysis.

Data Analysis. Data were screened for univariate outliers using *z*-scores > ± 3.29 and multivariate outliers using the Mahalanobis distance test ($p < .001$), as well as for the parametric assumptions that underlie repeated-measures (RM) (M)ANOVA. To assess the assumption of linearity between dependent variables, the relationship between remembered pleasure and forecasted pleasure was examined using a Pearson's product-moment correlation. Affective valence and RPE across the four conditions were assessed using two 4 (condition) × 4 (time) RM ANOVAs, while a oneway RM MANOVA was used to assess differences in remembered and forecasted pleasure across conditions. Order effects for affective valence and RPE were assessed by use of two 4 (exercise trial) × 4 (time) RM ANOVAs, and two oneway RM ANOVAs for remembered pleasure and forecasted pleasure. Follow-up *F* tests were Greenhouse–Geisser adjusted where necessary and supplemented by Bonferroni-adjusted pairwise comparisons.

Results

No univariate or multivariate outliers emerged during data screening, and no participants correctly identified the study purpose or reported any awareness that visual primes had been embedded in the video, therefore all data were retained for analysis. The Pearson's correlation coefficient for the relationship between remembered pleasure and forecasted pleasure ($r = .53$) confirmed a moderate relationship, thus nullifying concerns regarding multicollinearity.

In-task Affective Valence. There was a significant main effect of condition for in-task affective valence, $F(2.28, 61.54) = 17.04$, $p < .001$, $\eta_p^2 = 0.39$. Pairwise comparisons indicated significantly higher scores in the PRIME condition compared to the MV condition ($p = .040$,

Cohen's $d = 0.31$) and control ($p < .001$, $d = 0.86$), but no significant difference between PRIME and M conditions ($p = .062$, $d = 0.31$). A significant condition × time interaction was found for affective valence, $F(5.18, 139.81) = 3.06$, $p = .011$, $\eta_p^2 = 0.10$. Simple effects tests indicated that in-task affective valence scores were significantly higher in the PRIME condition compared to the other three conditions at Minutes 2, 6, and 8 (see Fig. 1). Affective valence scores were significantly lower in the control condition compared to the other conditions at all time points. No significant differences in exercise trial were found for affective valence, $F(3, 81) = 1.39$, $p = .252$, $\eta_p^2 = 0.05$.

RPE. There was a significant main effect of condition for RPE, $F(2.14, 57.90) = 14.42$, $p < .001$, $\eta_p^2 = 0.35$. Pairwise comparisons indicated significantly lower scores in the PRIME condition compared to the M condition ($p = .033$, $d = 0.47$) and control ($p < .001$, $d = 0.90$). There was no significant difference in RPE between the PRIME and MV conditions ($p = .051$) although a medium effect size emerged ($d = 0.45$). There was a significant condition × time interaction for RPE, $F(4.58, 123.67) = 4.54$, $p = .001$, $\eta_p^2 = 0.14$. RPE was significantly ($p < .01$) lower in the PRIME condition compared to the other conditions at Minutes 6 and 8, and significantly lower than control at all time points (see Fig. 2). There was no significant difference in RPE between the M and MV conditions at any time point. No significant differences in exercise trial were found for RPE, $F(3, 81) = 1.56$, $p = .205$, $\eta_p^2 = 0.06$.

Remembered Pleasure and Forecasted Pleasure. The MANOVA used to assess remembered and forecasted pleasure indicated a significant difference across conditions: Pillai's Trace = 0.71, $F(6, 162) = 14.87$, $p < .001$, $\eta_p^2 = 0.36$. Step-down F tests indicated significant differences across conditions in remembered pleasure, $F(2,51) = 56.21$, $p < .001$, $\eta_p^2 = 0.68$, and forecasted pleasure, $F(3,81) = 49.74$, $p < .001$, $\eta_p^2 = 0.65$; both associated with large effect sizes.

Pairwise comparisons indicated that remembered pleasure was significantly higher following the PRIME condition compared to M ($p < .001$, $d = 0.82$), MV ($p = .003$, $d = 0.58$), and control ($p < .001$, $d = 2.42$) conditions. Remembered pleasure was significantly higher following the M condition when compared to control ($p < .001$, $d = 1.49$), as well as in the MV condition when compared to control ($p < .000$, $d = 1.97$). No differences emerged between M and MV conditions in terms of remembered pleasure.

Pairwise comparisons for forecasted pleasure indicated significantly higher scores following the PRIME condition compared to M ($p = .005$, $d = 0.69$), MV ($p = .049$, $d = 0.52$), and control ($p < .001$, $d = 2.60$). Forecasted pleasure was significantly higher following M when compared to control ($p < .001$, $d = 1.70$), as well as after the MV condition when compared to control ($p < .001$, $d = 1.93$). No differences were observed between M and MV conditions in terms of forecasted pleasure (see Fig. 3). No significant differences in exercise trial were found for remembered pleasure, $F(3, 81) = .43$, $p = .732$, $\eta_p^2 = 0.02$, or forecasted pleasure, $F(3, 81) = .87$, $p = .459$, $\eta_p^2 = 0.03$.

Discussion

The primary aim of Study 1 was to examine the effects of music-video with embedded subliminal primes on affective states during and immediately after an exercise bout. Findings indicated that PRIME elicited a more enjoyable exercise experience when compared to M or MV conditions. In-task affective valence was more positive, RPE was lower, while both remembered and forecasted pleasure were higher, thus providing support for the three hypotheses. Overall, it was evident that participants felt better during and after the PRIME condition.

A possible limitation of Study 1 is the lack of population validity, given that the sample consisted of young active females. As the majority of participants were regular exercisers, they

were likely to already have a more positively valenced response to exercise than less active individuals or those who do not necessarily enjoy participating in physical activity [8]. A second limitation concerns the repetition involved in the administration of four experimental conditions during one laboratory visit. However, the counterbalancing of conditions controlled for order effects, indicating that any residual fatigue did not bear influence on the results. Study 2 was designed to address such limitations by sampling from an inactive population and administrating tests over multiple days.

Study 2

The purpose of Study 2 was to investigate the effects of positively valenced affective primes embedded in music-videos on in-task affective valence, exercise enjoyment, remembered pleasure, and forecasted pleasure associated with exercise. It was hypothesized that a music-video with priming (PRIME) condition would lead to more positive in-task affective valence, greater enjoyment of exercise, higher remembered pleasure, and higher forecasted pleasure when compared to the same music-video (MV) without primes.

Method

Power analysis. A power analysis was conducted using G*Power 3.1 [24] to establish appropriate sample size for a 2 (condition) × 2 (time) RM ANOVA for in-task affective valence. Using the medium effect size reported in Study 1 ($\eta_p^2 = 0.10$, converted to $f = 0.33$), with an alpha level of .05, power at 0.8, and anticipating moderately correlated RMs ($r = .60$) the power analysis indicated that a minimum of 18 participants would be required. An additional six participants were recruited to protect against attrition and deletions due to outliers. This sample size is more than adequate for the anticipated analyses for the other dependent variables, all of which are associated with a large anticipated effect size ($f > .40$), established in Study 1.

Participants. Volunteer male (n = 3) and female (n = 21) participants (N = 24) were recruited using convenience sampling from a New England workplace. Study participants had the following characteristics: age, M = 38.4 years, SD = 7.2 (range: 18–30); BMI, M = 27.6 kg/m^2, SD = 7.7 (range: 20.0–55.6); body fat, M = 30.5%, SD = 8.9 (range: 23.1–60.5); race White = 83.3%, African American = 12.5%, and mixed race = 4.2%. The majority of participants (79%) were physically inactive in accord with ACSM guidelines (< 150 min of moderate-intensity exercise per week) [25].

Stimuli and Measures. The same music-video and music-video with affective primes was used as in Study 1. Similarly, in-task affective valence was assessed using the FS [33], remembered pleasure using a 200 mm VAS, and forecasted pleasure using the EVS [35]. Unique to Study 2, was the Physical Activity Enjoyment Scale (PACES-8) [42], which was administered immediately after each condition to assess overall exercise enjoyment. Higher PACES-8 scores reflect greater levels of enjoyment. RPE was not included as a dependent variable in Study 2 given that a target RPE was used to regulate exercise intensity (see Procedure below).

Procedure. Approval from the Institutional Review Board of the second author was received and all participants provided written informed consent prior to participation. Upon arrival at the laboratory for the first session, participants' body mass (kg) and height (cm) were determined using a physician's scale (Detecto 437) and body composition was assessed using bioelectrical impedance (Tanita BC 418). Participants then completed a baseline trial to establish workload associated with "moderate intensity" perceived exertion (CR-10 RPE = 3) using a production protocol.

Prior to the trial, participants were provided with detailed instructions on use of the RPE scale in *production mode* [43]. This mode entails a participant adjusting her/his exercise load

(treadmill speed, incline, or both) to match the researcher-specified target RPE value. Numerous studies have confirmed the validity of perceptually regulated exercise intensity that is guided by RPE; indeed, correlations with heart rate, blood lactate concentration, and maximal oxygen uptake are reportedly higher for the production mode compared to the estimation mode [44]. Upon starting the baseline trial, participants walked on the treadmill at 2 mph and were asked to make upward adjustments to treadmill velocity and/or grade in order to reach the target RPE as quickly as possible. They were able to make additional adjustments, if needed, after 5 min (i.e., at the midpoint of the 10-min trial). The treadmill velocity and grade were recorded, along with participants' HR, and used to set the intensity for the subsequent experimental trials.

Participants returned 48 hr later to complete the first of two experimental trials, intended to elucidate the additive effect of subliminal primes. Following a series of dynamic stretches, participants completed 10 min of brisk walking (at their previously established speed and grade) under one of two counterbalanced conditions; MV or PRIME. Both videos were delivered using a 10.5″ tablet (Galaxy Tab A, Samsung) positioned on the treadmill console, and audio was delivered at a standardized volume (75 dBA) using over-ear headphones (Bose QuietComfort 35). Affective valence during exercise was measured at the midpoint (Minute 5) and just prior to the end of the task, and enjoyment was measured immediately after the task. Participants were afforded a 5-min rest period, following which, the VAS and EVS were used to assess remembered and forecasted pleasure, respectively. After 48 hr, participants returned for the second test session. To avoid distraction or any undue influence during testing, the experimenters interacted with participants only when collecting data; at all other times they stood slightly behind participants, outside of their sightline. A funneled debriefing procedure [15] was used to check for awareness of the primes, as in Study 1.

Data Analysis. Data were screened for univariate outliers using *z*-scores > ±3.29 and multivariate outliers using the Mahalanobis distance test with $p < .001$, as well as for the parametric assumptions that underlie RM (M)ANOVA. In-task affective valence scores were compared by use of a 2 (condition; MV and PRIME) × 2 (time; Minute 5 and Minute 10) RM ANOVA, while exercise enjoyment was compared between conditions by use of a paired-samples *t* test. Finally, oneway RM MANOVA was used to assess differences in remembered and forecasted pleasure between conditions. Follow-up *F* tests were Greenhouse-Geisser adjusted where necessary and supplemented by Bonferroni-adjusted pairwise comparisons.

Results

No participant indicated that they were aware of the primes, therefore all data were retained for analysis. No univariate or multivariate outliers emerged during data screening. A Pearson's correlation coefficient for the relationship between remembered and forecasted pleasure ($r = .62$) showed a moderate relationship, dispelling concerns of multicollinearity.

Heart Rate. There was no effect of condition for HR, $F(1, 23) = 1.17$, $p = .290$, $\eta_p^2 = 0.05$, confirming equivalent workload across MV and PRIME conditions.

In-task Affective Valence. There was a significant main effect of condition, $F(1, 23) = 13.02$, $p < .001$, $\eta_p^2 = 0.36$. In-task affective valence was significantly ($p < .001$) higher (i.e., more positive) in the PRIME condition (3.78 ± 1.01) compared to MV (3.15 ± 1.08). The condition × time interaction was nonsignificant, $F(1, 23) = 0.42$, $p = .524$, $\eta_p^2 = 0.02$.

Enjoyment. The paired-samples *t* test for exercise enjoyment indicated a significant difference between the MV and PRIME conditions, $t(23) = 2.98$, $p = .007$, Cohen's $d = 0.42$. Enjoyment was greater in the PRIME condition (42.92 ± 6.22) compared to MV (40.17 ± 6.71).

Remembered Pleasure and Forecasted Pleasure. The MANOVA used to assess differences in remembered and forecasted pleasure indicated a significant difference between the MV and PRIME conditions, Pillai's Trace = .607, $F(2, 22) = 16.98$, $p < .001$, $\eta_p^2 = 0.61$. Step-down F tests indicated significant differences between conditions for remembered pleasure, $F(1,23) = 17.09$, $p < .001$, $\eta_p^2 = 0.43$, and forecasted pleasure, $F(1,23) = 26.74$, $p < .001$, $\eta_p^2 = 0.54$; both associated with large effect sizes. Pairwise comparisons indicated that both remembered and forecasted pleasure were significantly ($p < .001$) higher in the PRIME condition compared to MV.

Discussion

Study 2 sought to compare affective measures taken during and immediately after exercise and overall exercise enjoyment between two conditions (MV and PRIME) that were isolated in light of the Study 1 results. All research hypotheses were supported. The PRIME condition elicited more positively valenced affect during exercise and a more enjoyable exercise experience when compared to MV. Further, remembered and forecasted pleasure scores were significantly higher following the PRIME condition relative to MV. Findings are consistent with Study 1, and serve to demonstrate the efficacy of PRIME in improving the affective experience of exercise in a population of largely inactive and overweight adults.

A limitation of Study 2 is the focus on a comparison of two conditions (MV and PRIME) that did not examine music in isolation or include a no-extraneous stimuli control condition. However, several participants passed unsolicited comments to the effect that we exposed them to "identical" conditions. This is illustrative of participants being unaware of the subliminal primes embedded in the PRIME condition.

General Discussion

The purpose of the present pair of studies was to examine the efficacy of M, MV, and PRIME in modulating psychological responses during and immediately after a bout of continuous exercise among two distinct populations: young, mostly physically active females of normal weight and a largely inactive and overweight sample of middle-aged adults. In Study 1, the hypotheses that PRIME would elicit more positive in-task affect, lower RPE, and higher remembered/forecasted pleasure when compared to the other three conditions were supported. In Study 2, the hypotheses that PRIME would elicit more positive in-task affect, greater enjoyment, and higher remember/forecasted pleasure when compared to MV were all supported.

Affective Responses

Results from both of the present studies serve to support the notion that subliminal primes can elicit positive changes in affective responses both *during* and *following* exercise [cf. 22, 23]. The most original contribution of the present study is to demonstrate the *additive effect* of affective primes across two distinct populations. Specifically, we know from previous work that music-only and music-video can enhance affective responses in the exercise context [e.g., 10, 11] but the effects of subliminal priming have remained largely untapped, both in research and applied contexts. The present findings illustrate stronger effects for music-video with embedded affective primes when contrasted with those of music-video alone. The findings are in line with those of Loizou and Karageorghis [23] who demonstrated positive affective changes in response to a music-video-priming condition administered preexercise.

The hedonic principle relates to the notion that a positive affective response to a given experience increases the likelihood of attempts to repeat that experience [45]. Therefore, if an individual experiences positive affect during and after exercise, this is likely to increase the

likelihood of reengagement in that exercise [e.g., 5, 46]. Moreover, repeated bouts of pleasurable exercise are thought to result in positive affective associations that might bias future decision-making in favor of exercise [46, 47].

In-task affective valence is a reliable predictor of future physical activity [6, 46]. In addition, an extensive body of work supports the importance of affective attitudes and anticipated affective reactions in predicting both exercise intentions and exercise behavior [8, 48]. The increase in remembered pleasure and forecasted pleasure observed in the present studies suggests that priming elicits carryover effects that can influence postexercise recollections and affective evaluations. This is important, given that behavioral decisions are shaped by people's predictions about how they might feel in the future, and such predictions draw heavily upon relevant past experiences [49].

Collectively, the present findings indicate that priming may be a viable intervention strategy for the enhancement of exercise-related affect. Notably, the PRIME vs. MV comparisons for in-task affective valence and remembered pleasure were associated with a larger effect size in Study 2 (Cohen's d = 0.60 and 0.89, respectively) than for the same comparisons in Study 1 (d = 0.31 and 0.58, respectively). This illustrates the increased potential for affective primes to enhance the exercise experience in less active populations.

Perceived Exertion

RPE is expected to increase over time during the course of a fixed-intensity exercise bout, as the exerciser gradually becomes more fatigued. It can, however, be moderated via use of external cues; at least at low-to-moderate intensities [50]. The combination of auditory and visual stimuli slightly extends, in physiological terms, the "efficacy zone" in which an individual can dissociate (i.e., focus outwardly rather on interoceptive cues) while exercising [10]. Study 1

findings (see Fig. 2) show that the PRIME condition elicited the lowest and most stable RPE scores during the 8-min exercise bout.

One possible explanation for the extension of the efficacy zone is that the use of music during exercise shifts the oxygenation curve observed in the dorsolateral prefrontal cortex toward slightly higher levels of intensity [51]. It seems plausible that the addition of video and priming to musical stimuli might further extend the efficacy zone, presumably due to a lower level of experienced displeasure. In a study with music-only conditions, Karageorghis and Jones [52] demonstrated that the attentional shift that promotes dissociation is in the region of 10% HRR; ostensibly, participants crossed from dissociation to association at an exercise intensity that was 10% higher with music vs. no-music control (i.e., 70% HRR vs. 80% HRR). An opportunity for future research lies in testing the attentional shift phenomenon with singular and plural audiovisual stimuli. Does the use of multiple stimuli (e.g., PRIME) result in a larger gain in attentional shift than ~10% HRR?

Limitations and Future Directions

Participants in Study 1 were all women and, in Study 2, were predominantly women, which serves to limit the generalizability of the present findings. Nonetheless, women are severely under-represented in exercise psychology research [53], therefore the present duplet of studies goes a small way toward redressing this imbalance. It is suggested that the experiments presented herein should be replicated with men or a mixed-sex sample and should consider other demographic/health-related factors not reported in the present studies (e.g., socioeconomic status, education level, visual or hearing impairments). Time constraints resulted in the use of 8-min exercise bouts in Study 1 and 10-min bouts in Study 2. The ACSM guidelines recommend that exercise sessions be of at least 10-min duration in order to count toward daily activity [25].

Therefore, future research should examine whether the present results can be replicated in longer duration exercise bouts (i.e., > 10 min).

Visual priming interventions are limited to exercise settings where there is a screen for participants to watch, potentially reducing the reach of such interventions. Nonetheless, viewing a screen during exercise is commonplace in health and fitness facilities wherein many cardio machines now come with built-in screens. Interactive, on-demand exercise programs during which participants watch a screen while working out at home, have gained popularity in recent years. It may be possible to integrate affective priming into the visual interface of a Peloton stationary bike or Mirror in-home fitness solution to deliver positive messages and thus enhance the exercise experience. The music-video-priming intervention presented herein can be deployed rapidly and cost-effectively. There is a need, however, to test the efficacy of the intervention beyond the realms of a controlled laboratory setting and on smaller devices, such as smartphones or tablets. Our positive findings provide impetus for future studies to assess the effect of such an intervention that is administered under more variable, real-world conditions.

Conclusions

From Study 1, in the absence of screens, music can confer a range of mild psychological and psychophysical benefits, as has been reported in numerous past studies [e.g., 11, 40]. The combination of music with video confers greater benefits than music alone but previous work shows this to be so only at low-to-moderate exercise intensities [e.g., 10, 54]. The novel implication to emanate from the present findings is that subliminal primes that are embedded in music-video confer benefits through more positively valenced affective responses during moderate-intensity exercise, that are above and beyond those conferred by music-video ($M_{\text{Cohen's } d}$ for MV vs. PRIME [all DVs in Study 1 and Study 2] = 0.64). The overall psychological

benefits are moderate in statistical terms and it would be advisable for the effects reported herein to be retested by several groups of independent researchers in order to establish their robustness.

Barriers to habitual physical activity among the general population include perceived discomfort [55] and displeasure experienced during exercise [46]. The combined stimuli of music, video, and positively valenced affective primes might then have a role to play in relieving such barriers at moderate levels of exercise intensity. Such stimuli can be used in contexts where there is the potential or need to create an activation state that is suitable for physical activity (e.g., a health center reception area or in a clinical exercise facility) [23]. Moreover, such stimuli can enhance people's feelings during exercise as well as make them feel better about both the exercise they have completed, and exercise that they *might* complete in the future, as illustrated in both sets of findings herein.

The findings pertaining to more positive in-task affective valence suggest that future studies should examine the potential for priming effects to endure in related intervention programs directed toward the promotion of exercise adherence [6, 46]. It is clear that work of a longitudinal nature needs to be undertaken to examine this notion. Moreover, it is conceivable that the "efficacy zone" in which music-video takes effect (i.e., the range of exercise intensity), might be slightly extended by the presence of affective primes. This needs to be a topic of future investigation with both behavioral and mechanistic strands [see e.g., 51].

Finally, it would be advantageous to extend this line of work to "hard-to-reach" or "at risk" populations, such as people with obesity and/or hypokinetic diseases. Advertisers have become adept in the use of supraliminal visual primes to sell products and services to the general public [56]; a similar approach using subliminal primes might be applied by behavioral scientists to reduce the prevalence of inactivity and sedentary lifestyles.

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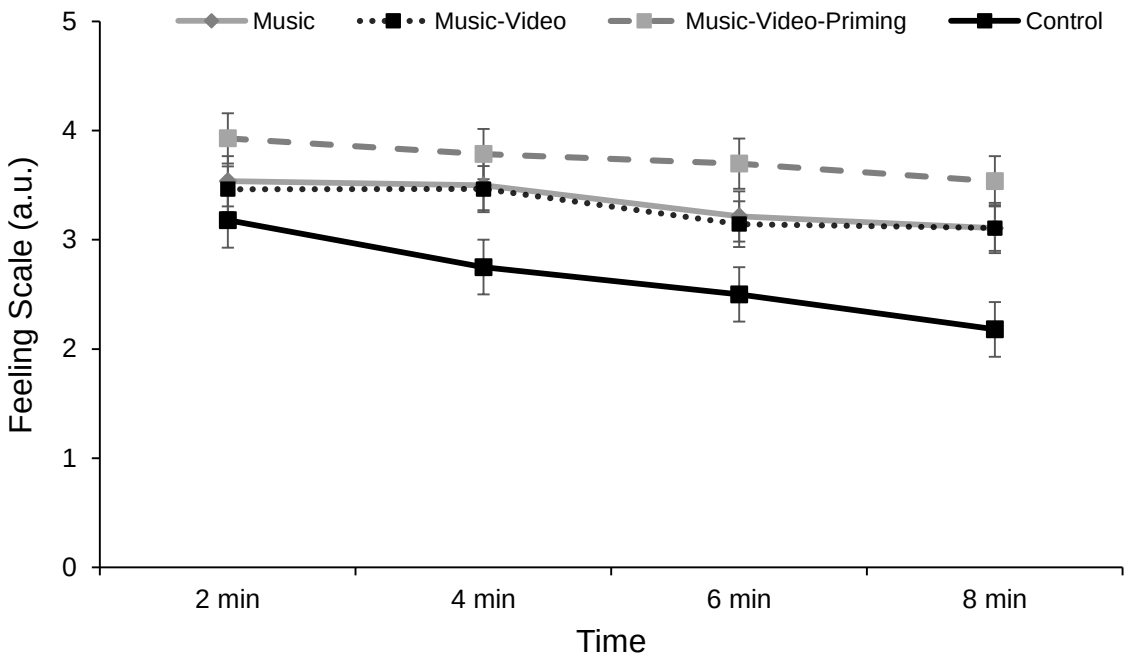


602

603 **Fig 1**. Significant condition × time interaction for in-task affective valence (p = .011); a.u.

604 arbitrary units; error bars denote standard error

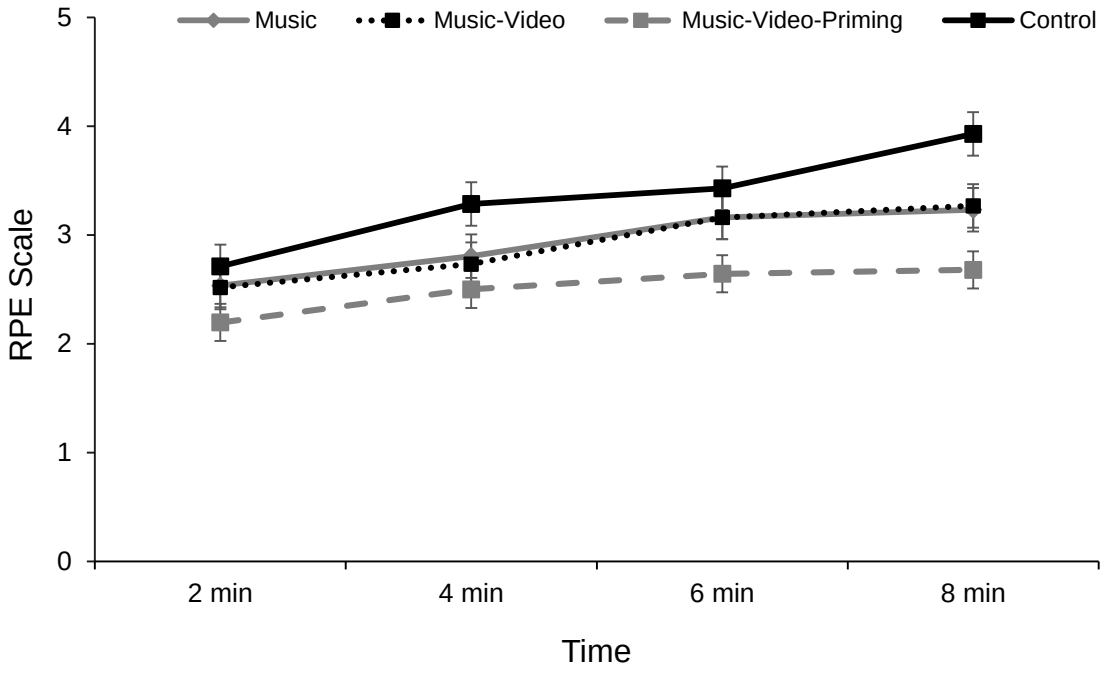
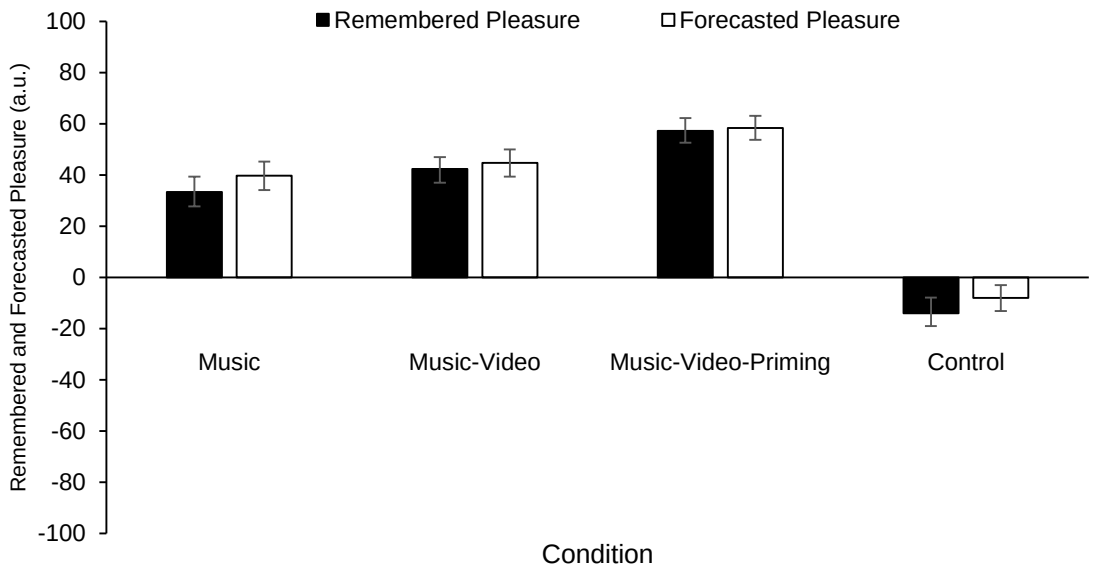


Fig 2. Significant condition × time interaction for RPE (p = .001); error bars denote standard error



608

609 **Fig 3**. Mean remembered and forecasted pleasure in four conditions; a.u. arbitrary units; error

610 bars denote standard error

Compliance with Ethical Standards

Ethical Approval All procedures performed in this study involving human participants were in accordance with the standards of the second author's institutional ethics committee (i.e., the host institution) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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Informed Consent Informed consent was obtained from all individual participants included in the study (see statement regarding consent in the Participants subsection).

Authors' Statement of Conflict of Interest and Adherence to Ethical Standards The authors declare that they have no conflict of interest. All procedures, including the informed consent process, were conducted in accordance with the ethical standards of the second author's institutional review board and with the Helsinki Declaration of 1975, as revised in 2000.