

Running Head: PRIMING AND MUSIC-VIDEO DURING EXERCISE

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

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## 10 Abstract

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

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

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

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

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

32 **Keywords** Affective response, dissociation, perceived exertion, subliminal priming

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## 34 Introduction

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

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

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

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4 58 passive, subtle, and unobtrusive activation of relevant mental representations by external stimuli,  
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6 59 without a person being consciously aware of the influence exerted by such stimuli [15]. Priming  
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9 60 manipulations can be either *subliminal* or *supraliminal*. In the case of supraliminal priming,  
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11 61 individuals are aware of an environmental cue, but are not aware of its influence on them [16].  
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14 62 Subliminal primes, which are the focus of the present pair of studies, are presented below the  
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16 63 threshold of conscious awareness, and are typically masked in some way in order to reduce or  
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19 64 eliminate conscious perception [17].  
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21 65       Research on interventions that target nonconscious processes is scant. Nonetheless, priming  
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23 66 has been studied in the context of *implicit attitudes*; the automatic affective responses forged  
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26 67 through particular associations with a given stimulus [18]. Implicit attitudes play a critical role in  
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29 68 regulating physical activity and this role is distinct from the influence of more reflective  
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31 69 processes [19]. These attitudes can be modified through a process known as *evaluative*  
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33 70 *conditioning*; this occurs when the valence of a stimulus is changed due to pairing it with another  
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36 71 stimulus that can be either positive or negative [20]. A small body of work has emerged  
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38 72 concerning the impact of priming interventions on health-related behaviors. Blanchfield, Hardy,  
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41 73 and Marcora [21] assessed the effect of priming on rating of perceived exertion (RPE) and time  
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43 74 to exhaustion during a cycling task. Participants were primed with either happy or sad faces  
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45 75 during a visual vigilance task. Time to exhaustion was 12% longer and RPE significantly lower  
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48 76 in the happy face compared to the sad face condition.  
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50 77       Loizou, Karageorghis, and Bishop [22] demonstrated the efficacy of motivational words  
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53 78 embedded into video-with-music to positively influence emotional states and the psychological  
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55 79 needs that underlie intrinsic motivation. Subsequently, Loizou and Karageorghis [23] examined  
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58 80 both the singular and interactive effects of pre-task video, music, and priming conditions on  
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4 81 affective state and anaerobic performance among male athletes. The motivational primes were  
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6 82 *Push, Drive, and Go* – words that the authors deemed relevant to the anaerobic test. The  
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9 83 combined video, music, and primes condition was the most effective in terms of optimizing  
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11 84 participants' pretask affect (valence and arousal) and subsequent anaerobic performance. The  
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14 85 authors concluded that music-video with primes provided an effective means by which to  
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16 86 activate psychological states and internal readiness prior to an anaerobic exercise task. They  
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19 87 suggested that future research should examine priming effects in more diverse populations,  
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21 88 during longer aerobic exercise tasks, and at different time points (i.e., during and after exercise).

### 23 89 **Study 1**

26 90 The purpose of Study 1 was to investigate the effects of **positively valenced** affective  
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28 91 primes embedded in music-videos on affective valence and RPE during exercise, and on  
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31 92 remembered pleasure and forecasted pleasure immediately following exercise. The study  
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33 93 employed a within-subjects design that required participants to complete a brisk walking task  
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36 94 under four conditions: music (M), music-video (MV), music-video with subliminal primes  
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38 95 (PRIME), and control. It was hypothesized that the PRIME condition would lead to more  
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41 96 positive in-task affective valence and lower RPE, coupled with higher remembered and  
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43 97 forecasted pleasure when compared to M, MV, and control conditions.

### 45 98 **Method**

48 99 **Power Analysis.** A power analysis using G\*Power software [24] was conducted for a 4  
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50 100 (condition)  $\times$  4 (time) RM ANOVA for in-task affective valence based on a predicted medium  
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53 101 effect size ( $f = 0.25$ ) [10], an alpha level of .05, and power of 0.8. This indicated that a minimum  
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55 102 of 24 participants would be required. An extra four participants were recruited to protect against  
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58 103 attrition and deletions due to outliers.

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4 104 **Participants.** Volunteer females ( $N = 28$ ) were recruited from a New England college by  
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7 105 use of convenience sampling. Study participants exhibited the following characteristics: age,  $M =$   
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9 106 22.6 years,  $SD = 3.3$  (range: 18–30); BMI,  $M = 23.9 \text{ kg/m}^2$ ,  $SD = 4.1$  (range: 19.2–36.6); body  
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11 107 fat,  $M = 28.3\%$ ,  $SD = 8.5$  (range: 17.6–50.2); race, White = 86%, Asian = 3%, other = 11%. The  
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13 108 majority (86%) of participants were physically active in accord with ACSM guidelines (> 150  
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16 109 min of moderate-intensity exercise/week) [25].

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19 110 **Stimuli and Measures.** The audiovisual stimuli were selected using criteria pertaining to  
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21 111 motivational music (> 120 beats per minute [bpm]) outlined by Karageorghis and Terry [26] and  
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23 112 criteria for motivational music-videos presented by Hutchinson et al. [10]. A focus group of  
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25 113 female students at a New England college rated a series of music-videos on the salient facets of  
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28 114 rhythm, style, melody, tempo, instrumentation, and beat using the Brunel Music Rating  
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30 115 Inventory-2 (BMRI-2) [27], a validated instrument designed to assess the motivational qualities  
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32 116 of music in an exercise context. The affective qualities of the music videos were rated by use of  
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35 117 the Affect Grid [28]. The two tracks used in the experimental conditions were *Good Feeling* by  
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37 118 Flo Rida (129 bpm) and *I Can Only Imagine* by David Guetta feat. Chris Brown and Lil Wayne  
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40 119 (128 bpm). These tracks elicited BMRI-2 scores of 30–32 (out of a possible 42), which are  
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42 120 indicative of strong motivational qualities in the exercise context [27] and ratings in the upper-  
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44 121 right quadrant of the Affect Grid; associated with positive valence and high arousal.

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47 122 Affective primes consisting of positively valenced words (happy, pleased, joyful) were  
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49 123 embedded into the music-videos for the PRIME condition. These words were selected in accord  
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51 124 with their high valence ratings with reference to the Affective Norms for English Words database  
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53 125 [29]. Each word appeared on the screen for 16 ms during the music-video, which is below  
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56 126 the threshold for conscious perception [30]. Given that repeated exposures to primes lead to  
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4 127 stronger and longer lasting effects [31], embedded words appeared every 10 s throughout the  
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6 128 music-video. To prevent possible habituation to the positive words [32], two-thirds of the words  
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9 129 were neutral (table, pencil, tree), and one-third comprised the positively valenced words.

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11 In-task affective valence was assessed by use of the Feeling Scale (FS) [33]; a single-item  
12 130 scale that measures how an individual feels during exercise with possible responses ranging from  
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14 131 scale that measures how an individual feels during exercise with possible responses ranging from  
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16 132 -5 (*very bad*) to +5 (*very good*). RPE was measured by use of Borg's CR-10 Scale [34], which  
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19 133 ranges from 0 (*nothing at all*) to 10 (*extremely strong*). Remembered pleasure was measured  
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21 134 using a 200-mm visual analog scale (VAS). Respondents were administered the item, "How did  
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24 135 the exercise session make you feel?", with responses ranging from -100 (*very unpleasant*) to  
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26 136 +100 (*very pleasant*). **Participants** drew a line through the point along the scale that best  
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29 137 represented how **they** felt during the exercise bout; a ruler was used to determine the exact score.  
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31 138 Finally, forecasted pleasure was assessed by use of the single-item Empirical Valence Scale  
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33 139 (EVS) [35]. The EVS has empirically spaced verbal descriptors along a continuous visual  
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36 140 analogue-scale ranging from -100 (*most unpleasant imaginable*) to +100 (*most pleasant*  
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38 141 *imaginable*) [35]. Participants were asked "If you repeated the exercise session again, how do  
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41 142 you think it would make you feel?" and marked their response on the EVS. Forecasted and  
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43 143 remembered pleasure were assessed using a different scale to those used in-task (i.e., the FS) in  
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46 144 order to minimize common method variance [36].

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48 145 **Procedure.** Approval from the Institutional Review Board of the second author was  
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50 146 received and all participants provided written informed consent. Participants were asked to  
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53 147 refrain from high-intensity exercise for 24 hr prior to each session. At the first session,  
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55 148 **participants'** body mass (kg) and body composition were assessed using bioelectrical impedance  
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58 149 (Tanita BC 418). A pretest to establish **participants'** maximum heart rate (HR<sub>max</sub>) was then  
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4 150 administered using the Bruce Treadmill Protocol [37]. **Participants were** asked to rate affective  
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6 151 valence and RPE every 2 min using the FS and Borg CR-10 Scale, respectively. This served as a  
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9 152 form of scale familiarization prior to experimental conditions. Heart rate (HR) was monitored  
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12 153 and recorded throughout the test using a HR monitor (Polar Electro Inc.).  
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14 154 On completion of the pretest, there was a 20-min recovery period followed by a  
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16 155 habituation session. The Karvonen formula [38] was used to calculate exercise HR for 65% heart  
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19 156 rate reserve (HRR) based upon the HRmax recorded in the pretest. This intensity was chosen to  
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21 157 test the novel priming intervention, as it **approximates** the intensity at which **dissociative**  
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23 158 **strategies work most effectively to influence affective response [39, 40]**. For the habituation  
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26 159 protocol, participants walked on a treadmill that gradually increased in velocity, in order to  
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29 160 establish the velocity associated with their 65% HRR. The speed at which HR stabilized at 65%  
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31 161 HRR for 2 min was the velocity used during the experimental phase.  
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33 162 **Participants** returned 48 hr later and **were** administered four experimental conditions:  
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36 163 Music (M), music-video (MV), music-video with primes (PRIME), and control (no music, video,  
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38 164 or priming). Audiovisual stimuli were delivered using a 13" tablet (HP Split x2, HP Inc.)  
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41 165 positioned on the treadmill console, with the tablet speaker set at a standardized sound intensity  
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43 166 of 75 dBA. To counter any potential order effects, a Williams' square was used to randomly  
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46 167 assign condition order. Each condition consisted of an 8-min brisk walking task during which  
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48 168 affective valence and RPE were measured at Minutes 2, 4, 6, and 8. Following each bout of  
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51 169 exercise, the VAS and EVS were used to assess remembered and forecasted pleasure,  
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53 170 respectively. **Participants were** then afforded a 5-min break during which a simple mental  
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55 171 arithmetic task was administered as a "filler" to mitigate any potential carryover effects [41].  
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58 172 This protocol was repeated under a different condition until all four conditions had been  
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4 173 completed. Thereafter, a funneled debriefing procedure [15] was used to assess whether  
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6 174 **participants were** aware of the affective primes. If any participant correctly identified the purpose  
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9 175 of the study or mentioned the primes, her data would not have been included for analysis.

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11 176 **Data Analysis.** Data were screened for univariate outliers using  $z$ -scores  $> \pm 3.29$  and  
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14 177 multivariate outliers using the Mahalanobis distance test ( $p < .001$ ), as well as for the parametric  
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16 178 assumptions that underlie repeated-measures (RM) (M)ANOVA. To assess the assumption of  
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19 179 linearity between dependent variables, the relationship between remembered pleasure and  
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21 180 forecasted pleasure was examined using a Pearson's product-moment correlation. Affective  
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24 181 valence and RPE across the four conditions were assessed using two 4 (condition)  $\times$  4 (time) RM  
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26 182 ANOVAs, while a oneway RM MANOVA was used to assess differences in remembered and  
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29 183 forecasted pleasure across conditions. Order effects for affective valence and RPE were assessed  
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31 184 by use of two 4 (exercise trial)  $\times$  4 (time) RM ANOVAs, and two oneway RM ANOVAs for  
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34 185 remembered pleasure and forecasted pleasure. Follow-up  $F$  tests were Greenhouse–Geisser  
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36 186 adjusted where necessary and supplemented by Bonferroni-adjusted pairwise comparisons.

## 37 38 187 **Results**

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41 188 No univariate or multivariate outliers emerged during data screening, and no participants  
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43 189 correctly identified the study purpose or reported any awareness that visual primes had been  
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46 190 embedded in the video, therefore all data were retained for analysis. The Pearson's correlation  
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48 191 coefficient for the relationship between remembered pleasure and forecasted pleasure ( $r = .53$ )  
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51 192 confirmed a moderate relationship, thus nullifying concerns regarding multicollinearity.

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53 193 **In-task Affective Valence.** There was a significant main effect of condition for in-task  
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55 194 affective valence,  $F(2.28, 61.54) = 17.04, p < .001, \eta_p^2 = 0.39$ . Pairwise comparisons indicated  
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58 195 significantly higher scores in the PRIME condition compared to the MV condition ( $p = .040$ ,

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4 196 Cohen's  $d = 0.31$ ) and control ( $p < .001$ ,  $d = 0.86$ ), but no significant difference between PRIME  
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7 197 and M conditions ( $p = .062$ ,  $d = 0.31$ ). A significant condition  $\times$  time interaction was found for  
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9 198 affective valence,  $F(5.18, 139.81) = 3.06$ ,  $p = .011$ ,  $\eta_p^2 = 0.10$ . Simple effects tests indicated that  
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11 199 in-task affective valence scores were significantly higher in the PRIME condition compared to  
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14 200 the other three conditions at Minutes 2, 6, and 8 (see Fig. 1). Affective valence scores were  
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16 201 significantly lower in the control condition compared to the other conditions at all time points.  
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19 202 No significant differences in exercise trial were found for affective valence,  $F(3, 81) = 1.39$ ,  $p =$   
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21 203  $.252$ ,  $\eta_p^2 = 0.05$ .

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24 204 **RPE.** There was a significant main effect of condition for RPE,  $F(2.14, 57.90) = 14.42$ ,  $p$   
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26 205  $< .001$ ,  $\eta_p^2 = 0.35$ . Pairwise comparisons indicated significantly lower scores in the PRIME  
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29 206 condition compared to the M condition ( $p = .033$ ,  $d = 0.47$ ) and control ( $p < .001$ ,  $d = 0.90$ ).  
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31 207 There was no significant difference in RPE between the PRIME and MV conditions ( $p = .051$ )  
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33 208 although a medium effect size emerged ( $d = 0.45$ ). There was a significant condition  $\times$  time  
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36 209 interaction for RPE,  $F(4.58, 123.67) = 4.54$ ,  $p = .001$ ,  $\eta_p^2 = 0.14$ . RPE was significantly ( $p < .01$ )  
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38 210 lower in the PRIME condition compared to the other conditions at Minutes 6 and 8, and  
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41 211 significantly lower than control at all time points (see Fig. 2). There was no significant difference  
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43 212 in RPE between the M and MV conditions at any time point. No significant differences in  
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46 213 exercise trial were found for RPE,  $F(3, 81) = 1.56$ ,  $p = .205$ ,  $\eta_p^2 = 0.06$ .

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48 214 **Remembered Pleasure and Forecasted Pleasure.** The MANOVA used to assess  
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51 215 remembered and forecasted pleasure indicated a significant difference across conditions: Pillai's  
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53 216 Trace = 0.71,  $F(6, 162) = 14.87$ ,  $p < .001$ ,  $\eta_p^2 = 0.36$ . Step-down  $F$  tests indicated significant  
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55 217 differences across conditions in remembered pleasure,  $F(2,51) = 56.21$ ,  $p < .001$ ,  $\eta_p^2 = 0.68$ , and  
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58 218 forecasted pleasure,  $F(3,81) = 49.74$ ,  $p < .001$ ,  $\eta_p^2 = 0.65$ ; both associated with large effect sizes.  
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4 219 Pairwise comparisons indicated that remembered pleasure was significantly higher following the  
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6 220 PRIME condition compared to M ( $p < .001$ ,  $d = 0.82$ ), MV ( $p = .003$ ,  $d = 0.58$ ), and control ( $p <$   
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9 221  $.001$ ,  $d = 2.42$ ) conditions. Remembered pleasure was significantly higher following the M  
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11 222 condition when compared to control ( $p < .001$ ,  $d = 1.49$ ), as well as in the MV condition when  
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14 223 compared to control ( $p < .000$ ,  $d = 1.97$ ). No differences emerged between M and MV conditions  
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16 224 in terms of remembered pleasure.

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19 225 Pairwise comparisons for forecasted pleasure indicated significantly higher scores  
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21 226 following the PRIME condition compared to M ( $p = .005$ ,  $d = 0.69$ ), MV ( $p = .049$ ,  $d = 0.52$ ),  
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23 227 and control ( $p < .001$ ,  $d = 2.60$ ). Forecasted pleasure was significantly higher following M when  
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26 228 compared to control ( $p < .001$ ,  $d = 1.70$ ), as well as after the MV condition when compared to  
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29 229 control ( $p < .001$ ,  $d = 1.93$ ). No differences were observed between M and MV conditions in  
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31 230 terms of forecasted pleasure (see Fig. 3). No significant differences in exercise trial were found  
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33 231 for remembered pleasure,  $F(3, 81) = .43$ ,  $p = .732$ ,  $\eta_p^2 = 0.02$ , or forecasted pleasure,  $F(3, 81) =$   
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36 232  $.87$ ,  $p = .459$ ,  $\eta_p^2 = 0.03$ .

## 37 38 233 **Discussion**

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40 234 The primary aim of Study 1 was to examine the effects of music-video with embedded  
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43 235 subliminal primes on affective states during and immediately after an exercise bout. Findings  
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45 236 indicated that PRIME elicited a more enjoyable exercise experience when compared to M or MV  
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48 237 conditions. In-task affective valence was more positive, RPE was lower, while both remembered  
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51 238 and forecasted pleasure were higher, thus providing support for the three hypotheses. Overall, it  
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53 239 was evident that participants felt better during and after the PRIME condition.

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55 240 A possible limitation of Study 1 is the lack of population validity, **given that** the sample  
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58 241 consisted of young active females. **As the majority of participants were regular exercisers, they**

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4 242 were likely to already have a more positively valenced response to exercise than less active  
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6 243 individuals or those who do not necessarily enjoy participating in physical activity [8]. A second  
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9 244 limitation concerns the repetition involved in the administration of four experimental conditions  
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11 245 during one laboratory visit. However, the counterbalancing of conditions controlled for order  
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14 246 effects, indicating that any residual fatigue did not bear influence on the results. Study 2 was  
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16 247 designed to address such limitations by sampling from an inactive population and administrating  
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19 248 tests over multiple days.  
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## 21 249 Study 2

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24 250 The purpose of Study 2 was to investigate the effects of positively valenced affective  
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26 251 primes embedded in music-videos on in-task affective valence, exercise enjoyment, remembered  
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29 252 pleasure, and forecasted pleasure associated with exercise. It was hypothesized that a music-  
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31 253 video with priming (PRIME) condition would lead to more positive in-task affective valence,  
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34 254 greater enjoyment of exercise, higher remembered pleasure, and higher forecasted pleasure when  
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36 255 compared to the same music-video (MV) without primes.  
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## 38 256 Method

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41 257 **Power analysis.** A power analysis was conducted using G\*Power 3.1 [24] to establish  
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43 258 appropriate sample size for a 2 (condition)  $\times$  2 (time) RM ANOVA for in-task affective valence.  
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45  
46 259 Using the medium effect size reported in Study 1 ( $\eta_p^2 = 0.10$ , converted to  $f = 0.33$ ), with an  
47  
48 260 alpha level of .05, power at 0.8, and anticipating moderately correlated RMs ( $r = .60$ ) the power  
49  
50  
51 261 analysis indicated that a minimum of 18 participants would be required. An additional six  
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53 262 participants were recruited to protect against attrition and deletions due to outliers. This sample  
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55  
56 263 size is more than adequate for the anticipated analyses for the other dependent variables, all of  
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58 264 which are associated with a large anticipated effect size ( $f > .40$ ), established in Study 1.  
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4 265 **Participants.** Volunteer male ( $n = 3$ ) and female ( $n = 21$ ) participants ( $N = 24$ ) were  
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6 266 recruited using convenience sampling from a New England workplace. Study participants had  
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8  
9 267 the following characteristics: age,  $M = 38.4$  years,  $SD = 7.2$  (range: 18–30); BMI,  $M = 27.6$   
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11 268  $\text{kg/m}^2$ ,  $SD = 7.7$  (range: 20.0–55.6); body fat,  $M = 30.5\%$ ,  $SD = 8.9$  (range: 23.1–60.5); race  
12  
13 269 White = 83.3%, African American = 12.5%, and mixed race = 4.2%. The majority of participants  
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15  
16 270 (79%) were physically inactive in accord with ACSM guidelines (< 150 min of moderate-  
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19 271 intensity exercise per week) [25].  
20

21 272 **Stimuli and Measures.** The same music-video and music-video with affective primes  
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23  
24 273 was used as in Study 1. Similarly, in-task affective valence was assessed using the FS [33],  
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26 274 remembered pleasure using a 200 mm VAS, and forecasted pleasure using the EVS [35]. Unique  
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28  
29 275 to Study 2, was the Physical Activity Enjoyment Scale (PACES-8) [42], which was administered  
30  
31 276 immediately after each condition to assess overall exercise enjoyment. Higher PACES-8 scores  
32  
33 277 reflect greater levels of enjoyment. RPE was not included as a dependent variable in Study 2  
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35  
36 278 given that a target RPE was used to regulate exercise intensity (see Procedure below).  
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38 279 **Procedure.** Approval from the Institutional Review Board of the second author was  
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41 280 received and all participants provided written informed consent prior to participation. Upon  
42  
43 281 arrival at the laboratory for the first session, participants' body mass (kg) and height (cm) were  
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46 282 determined using a physician's scale (Detecto 437) and body composition was assessed using  
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48 283 bioelectrical impedance (Tanita BC 418). Participants then completed a baseline trial to establish  
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51 284 workload associated with "moderate intensity" perceived exertion (CR-10 RPE = 3) using a  
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53 285 production protocol.  
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55 286 Prior to the trial, participants were provided with detailed instructions on use of the RPE  
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58 287 scale in *production mode* [43]. This mode entails a participant adjusting her/his exercise load  
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4 288 (treadmill speed, incline, or both) to match the researcher-specified target RPE value. Numerous  
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6 289 studies have confirmed the validity of perceptually regulated exercise intensity that is guided by  
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9 290 RPE; indeed, correlations with heart rate, blood lactate concentration, and maximal oxygen  
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11 291 uptake are reportedly higher for the production mode compared to the estimation mode [44].  
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14 292 Upon starting the baseline trial, **participants** walked on the treadmill at 2 mph and **were** asked to  
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16 293 make upward adjustments to treadmill velocity and/or grade in order to reach the target RPE as  
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19 294 quickly as possible. **They were** able to make additional adjustments, if needed, after 5 min (i.e.,  
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21 295 at the midpoint of the 10-min trial). The treadmill velocity and grade were recorded, along with  
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24 296 **participants'** HR, and used to set the intensity for the subsequent experimental trials.

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26 297 **Participants** returned 48 hr later to complete the first of two experimental trials, intended  
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29 298 to elucidate the additive effect of subliminal primes. Following a series of dynamic stretches,  
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31 299 **participants** completed 10 min of brisk walking (at **their** previously established speed and grade)  
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33 300 under one of two counterbalanced conditions; MV or PRIME. Both videos were delivered using  
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36 301 a 10.5" tablet (Galaxy Tab A, Samsung) positioned on the treadmill console, and audio was  
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38 302 delivered at a standardized volume (75 dBA) using over-ear headphones (Bose  
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41 303 QuietComfort 35). Affective valence during exercise was measured at the midpoint (Minute 5)  
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43 304 and just prior to the end of the task, and enjoyment was measured immediately after the task.  
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45 305 **Participants were** afforded a 5-min rest period, following which, the VAS and EVS were used to  
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48 306 assess remembered and forecasted pleasure, respectively. After 48 hr, **participants** returned for  
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51 307 the second test session. To avoid distraction or any undue influence during testing, the  
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53 308 experimenters interacted with **participants** only when collecting data; at all other times they stood  
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55 309 slightly behind **participants**, outside of **their** sightline. A funneled debriefing procedure [15] was  
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58 310 used to check for awareness of the primes, as in Study 1.

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4 311 **Data Analysis.** Data were screened for univariate outliers using  $z$ -scores  $> \pm 3.29$  and  
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6 312 multivariate outliers using the Mahalanobis distance test with  $p < .001$ , as well as for the  
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9 313 parametric assumptions that underlie RM (M)ANOVA. In-task affective valence scores were  
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11 314 compared by use of a 2 (condition; MV and PRIME)  $\times$  2 (time; Minute 5 and Minute 10) RM  
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13 ANOVA, while exercise enjoyment was compared between conditions by use of a paired-  
14 315 ANOVA, while exercise enjoyment was compared between conditions by use of a paired-  
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16 316 samples  $t$  test. Finally, oneway RM MANOVA was used to assess differences in remembered  
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19 317 and forecasted pleasure between conditions. Follow-up  $F$  tests were Greenhouse-Geisser  
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21 318 adjusted where necessary and supplemented by Bonferroni-adjusted pairwise comparisons.  
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## 23 319 **Results**

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26 320 No participant indicated that they were aware of the primes, therefore all data were  
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29 321 retained for analysis. No univariate or multivariate outliers emerged during data screening. A  
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31 322 Pearson's correlation coefficient for the relationship between remembered and forecasted  
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33 323 pleasure ( $r = .62$ ) showed a moderate relationship, dispelling concerns of multicollinearity.  
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36 324 **Heart Rate.** There was no effect of condition for HR,  $F(1, 23) = 1.17, p = .290, \eta_p^2 =$   
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38 325  $0.05$ , confirming equivalent workload across MV and PRIME conditions.  
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41 326 **In-task Affective Valence.** There was a significant main effect of condition,  $F(1, 23) =$   
42  
43 327  $13.02, p < .001, \eta_p^2 = 0.36$ . In-task affective valence was significantly ( $p < .001$ ) higher (i.e.,  
44  
45 328 more positive) in the PRIME condition ( $3.78 \pm 1.01$ ) compared to MV ( $3.15 \pm 1.08$ ). The  
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48 329 condition  $\times$  time interaction was nonsignificant,  $F(1, 23) = 0.42, p = .524, \eta_p^2 = 0.02$ .  
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51 330 **Enjoyment.** The paired-samples  $t$  test for exercise enjoyment indicated a significant  
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53 331 difference between the MV and PRIME conditions,  $t(23) = 2.98, p = .007$ , Cohen's  $d = 0.42$ .  
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55 332 Enjoyment was greater in the PRIME condition ( $42.92 \pm 6.22$ ) compared to MV ( $40.17 \pm 6.71$ ).  
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4 333 **Remembered Pleasure and Forecasted Pleasure.** The MANOVA used to assess  
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6 334 differences in remembered and forecasted pleasure indicated a significant difference between the  
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9 335 MV and PRIME conditions, Pillai's Trace = .607,  $F(2, 22) = 16.98$ ,  $p < .001$ ,  $\eta_p^2 = 0.61$ . Step-  
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11 336 down  $F$  tests indicated significant differences between conditions for remembered pleasure,  
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13  
14 337  $F(1,23) = 17.09$ ,  $p < .001$ ,  $\eta_p^2 = 0.43$ , and forecasted pleasure,  $F(1,23) = 26.74$ ,  $p < .001$ ,  $\eta_p^2 =$   
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16 338 0.54; both associated with large effect sizes. Pairwise comparisons indicated that both  
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19 339 remembered and forecasted pleasure were significantly ( $p < .001$ ) higher in the PRIME condition  
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21 340 compared to MV.

## 23 341 **Discussion**

26 342 Study 2 sought to compare affective measures taken during and immediately after  
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29 343 exercise and overall exercise enjoyment between two conditions (MV and PRIME) that were  
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31 344 isolated in light of the Study 1 results. All research hypotheses were supported. The PRIME  
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33 345 condition elicited more **positively valenced affect** during exercise and a more enjoyable exercise  
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36 346 experience when compared to MV. Further, remembered and forecasted pleasure scores were  
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38 347 significantly higher following the PRIME condition relative to MV. Findings are consistent with  
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41 348 Study 1, and serve to demonstrate the efficacy of PRIME in improving the affective experience  
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43 349 of exercise in a population of largely inactive and overweight adults.

45 350 A limitation of Study 2 is the focus on a comparison of two conditions (MV and PRIME)  
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48 351 that did not examine music in isolation or include a no-extraneous stimuli control condition.  
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51 352 However, **several** participants passed unsolicited comments to the effect that we exposed them to  
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53 353 "identical" conditions. This is illustrative of participants being unaware of the subliminal primes  
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55 354 embedded in the PRIME condition.  
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## 356 **General Discussion**

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

## 365 **Affective Responses**

366       Results from both of the present studies serve to support the notion that subliminal primes  
367 can elicit positive changes in affective responses both *during* and *following* exercise [cf. 22, 23].  
368 The most original contribution of the present study is to demonstrate the *additive effect* of  
369 affective primes across two distinct populations. Specifically, we know from previous work that  
370 music-only and music-video can enhance affective responses in the exercise context [e.g., 10,  
371 11] but the effects of subliminal priming have remained largely untapped, both in research and  
372 applied contexts. **The present findings illustrate stronger effects for music-video with embedded  
373 affective primes when contrasted with those of music-video alone.** The findings are in line with  
374 those of Loizou and Karageorghis [23] who demonstrated positive affective changes in response  
375 to a music-video-priming condition administered preexercise.

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

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4 379 likelihood of reengagement in that exercise [e.g., 5, 46]. Moreover, repeated bouts of pleasurable  
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7 380 exercise are thought to result in positive affective **associations** that might bias future decision-  
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9 381 making in favor of exercise [46, 47].

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11 382 In-task affective valence is a reliable predictor of future physical activity [6, 46]. In  
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14 383 addition, an extensive body of work supports the importance of affective attitudes and  
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16 384 anticipated affective reactions in predicting both exercise intentions and exercise behavior [8,  
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19 385 48]. The increase in remembered pleasure and forecasted pleasure observed in the present studies  
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21 386 suggests that priming elicits carryover effects that can influence postexercise recollections and  
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24 387 affective evaluations. This is important, given that behavioral decisions are shaped by people's  
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26 388 predictions about how they might feel in the future, and such predictions draw heavily upon  
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29 389 relevant past experiences [49].

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31 390 Collectively, the present findings indicate that priming may be a viable **intervention**  
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33 391 **strategy** for the enhancement of exercise-related affect. Notably, the PRIME vs. MV  
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36 392 comparisons for in-task affective valence and remembered pleasure were associated with a larger  
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38 393 effect size in Study 2 (Cohen's  $d = 0.60$  and  $0.89$ , respectively) than for the same comparisons in  
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41 394 Study 1 ( $d = 0.31$  and  $0.58$ , respectively). This illustrates the increased potential for affective  
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43 395 primes to enhance the exercise experience in less active populations.

#### 44 45 396 **Perceived Exertion**

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48 397 RPE is expected to increase over time during the course of a **fixed**-intensity exercise  
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51 398 bout, as the exerciser gradually becomes more fatigued. It can, however, be moderated via use of  
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53 399 external cues; at least at low-to-moderate intensities [50]. The combination of auditory and visual  
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55 400 stimuli slightly extends, in physiological terms, the "efficacy zone" in which an individual can  
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58 401 dissociate (i.e., focus outwardly rather on interoceptive cues) while exercising [10]. Study 1  
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4 402 findings (see Fig. 2) show that the PRIME condition elicited the lowest and most stable RPE  
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6 403 scores during the 8-min exercise bout.

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9 404 One possible explanation for the extension of the efficacy zone is that the use of music  
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11 405 during exercise shifts the oxygenation curve observed in the dorsolateral prefrontal cortex toward  
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13 406 slightly higher levels of intensity [51]. It seems plausible that the addition of video and priming  
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16 407 to musical stimuli might further extend the efficacy zone, presumably due to a lower level of  
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18 408 experienced displeasure. In a study with music-only conditions, Karageorghis and Jones [52]  
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21 409 demonstrated that the attentional shift that promotes dissociation is in the region of 10% HRR;  
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23 410 ostensibly, participants crossed from dissociation to association at an exercise intensity that was  
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26 411 10% higher with music vs. no-music control (i.e., 70% HRR vs. 80% HRR). **An opportunity for**  
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28 412 **future research** lies in testing the attentional shift phenomenon with singular and plural  
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31 413 audiovisual stimuli. Does the use of multiple stimuli (e.g., PRIME) result in a larger gain in  
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33 414 attentional shift than ~10% HRR?

### 34 35 36 415 **Limitations and Future Directions**

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38 416 Participants in Study 1 were all women and, in Study 2, were predominantly women,  
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41 417 which serves to limit the generalizability of the present findings. Nonetheless, women are  
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43 418 severely under-represented in exercise psychology research [53], therefore the present duplet of  
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46 419 studies goes a small way toward redressing this imbalance. **It is suggested that the experiments**  
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48 420 **presented herein should be replicated with men or a mixed-sex sample and should consider other**  
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51 421 **demographic/health-related factors not reported in the present studies (e.g., socioeconomic**  
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53 422 **status, education level, visual or hearing impairments).** Time constraints resulted in the use of 8-  
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56 423 min exercise bouts in Study 1 and 10-min bouts in Study 2. The ACSM guidelines recommend  
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58 424 that exercise sessions be of at least 10-min duration in order to count toward daily activity [25].  
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4 425 Therefore, future research should examine whether the present results can be replicated in longer  
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6 426 duration exercise bouts (i.e., > 10 min).

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9 427 Visual priming interventions are limited to exercise **settings** where there is a screen for  
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11 428 participants to watch, potentially reducing the reach of such interventions. Nonetheless, **viewing**  
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14 429 a screen during exercise is commonplace in health and fitness facilities wherein many cardio  
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16 430 machines now come with built-in screens. Interactive, on-demand exercise programs during  
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19 431 which participants watch a screen while working out at home, have **gained** popularity in recent  
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21 432 years. It may be possible to integrate affective priming into the visual interface of a Peloton  
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24 433 stationary bike or Mirror in-home fitness solution to deliver positive messages and thus enhance  
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26 434 the exercise experience. The music-video-priming intervention presented herein can be deployed  
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29 435 rapidly and cost-effectively. There is a need, however, to test the efficacy of the intervention  
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31 436 beyond the realms of a controlled laboratory setting **and on smaller devices, such as smartphones**  
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34 437 **or tablets**. Our positive findings provide impetus for future studies to assess the effect of such an  
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36 438 intervention that is administered under more variable, real-world conditions.

### 37 38 439 **Conclusions**

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41 440 From Study 1, in the absence of screens, music can confer a range of mild psychological  
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43 441 and psychophysical benefits, as has been reported in numerous past studies [e.g., 11, 40]. The  
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46 442 combination of music with video confers greater benefits than music alone but previous work  
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48 443 shows this to be so only at low-to-moderate exercise intensities [e.g., 10, 54]. The novel  
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51 444 implication to emanate from the present findings is that subliminal primes that are embedded in  
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53 445 music-video confer **benefits through more positively valenced affective responses during**  
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56 446 **moderate-intensity exercise**, that are above and beyond those conferred by music-video ( $M_{Cohen}$ 's  
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58 447  $d$  for MV vs. PRIME [all DVs in Study 1 and Study 2] = 0.64). The overall psychological  
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4 448 benefits are moderate in statistical terms and it would be advisable for the effects reported herein  
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6 449 to be retested by several groups of independent researchers in order to establish their robustness.  
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9 450 Barriers to habitual physical activity among the general population include perceived  
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11 451 discomfort [55] and displeasure experienced during exercise [46]. The combined stimuli of  
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14 452 music, video, and **positively valenced** affective primes might then have a role to play in relieving  
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16 453 such barriers at moderate levels of exercise intensity. **Such stimuli can be used in contexts where**  
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19 454 **there is the potential or need to create an activation state that is suitable for physical activity**  
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21 455 **(e.g., a health center reception area or in a clinical exercise facility) [23]. Moreover, such stimuli**  
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23 456 **can enhance people's feelings during exercise as well as make them feel better about both the**  
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25 457 **exercise they have completed, and exercise that they *might* complete in the future, as illustrated**  
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28 458 **in both sets of findings herein.**  
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31 459 The findings pertaining to more positive in-task affective valence **suggest that future**  
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33 460 **studies should examine the potential for priming effects to endure in related intervention**  
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36 461 **programs directed toward** the promotion of exercise adherence [6, 46]. It is clear that work of a  
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38 462 longitudinal nature needs to be undertaken to examine this notion. Moreover, it is conceivable  
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40 463 that the “efficacy zone” in which music-video takes effect (i.e., the range of exercise intensity),  
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42 464 might be slightly extended by the presence of affective primes. This needs to be a topic of future  
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45 465 investigation with both behavioral and mechanistic strands [see e.g., 51].  
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48 466 Finally, it would be advantageous to extend this line of work to “hard-to-reach” or “at  
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50 467 risk” populations, such as people with obesity and/or **hypokinetic diseases**. Advertisers have  
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53 468 become adept in the use of supraliminal visual primes to sell products and services to the general  
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55 469 public [56]; a similar approach using subliminal primes might be applied by behavioral scientists  
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58 470 to **reduce the prevalence** of inactivity and sedentary lifestyles.  
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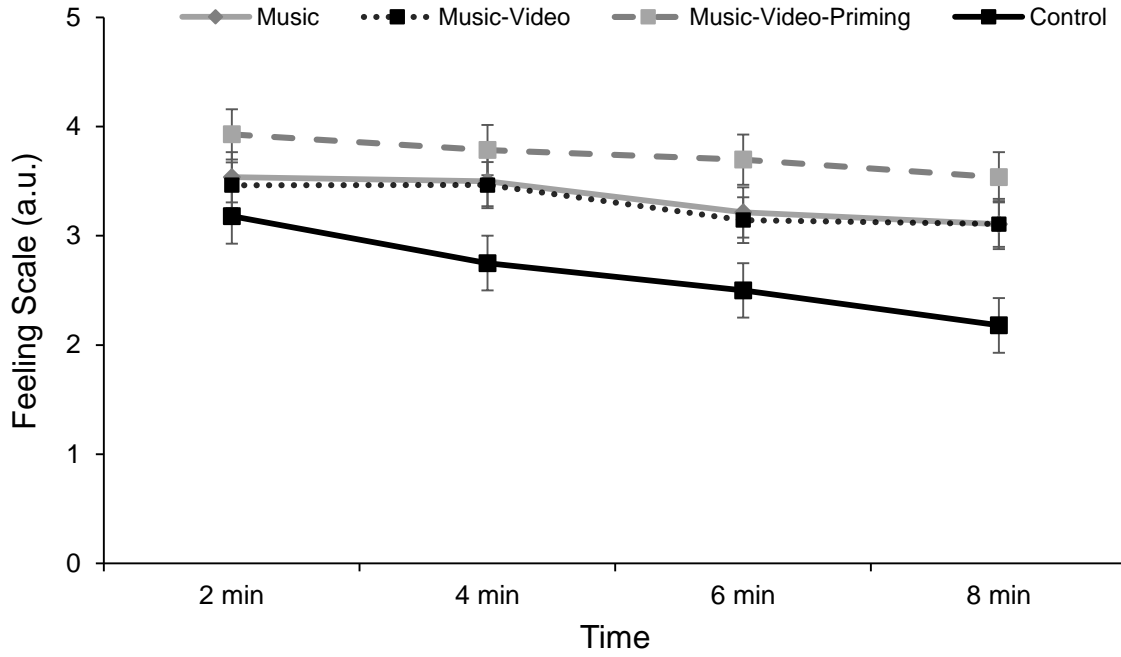


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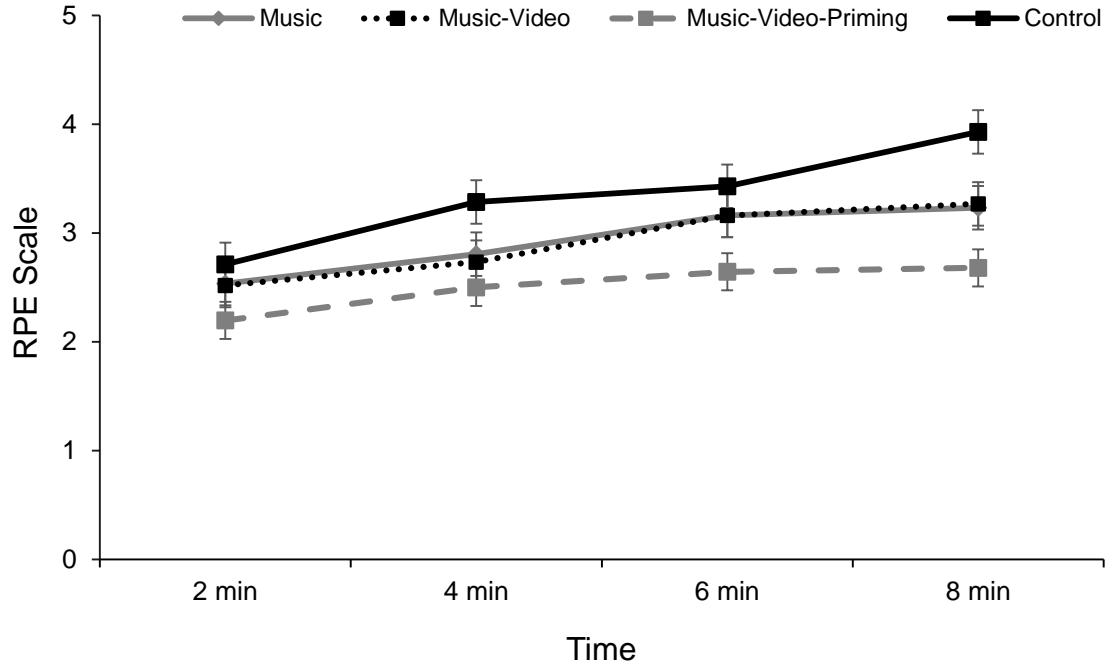


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603 **Fig 1.** Significant condition  $\times$  time interaction for in-task affective valence ( $p = .011$ ); a.u.

604 arbitrary units; error bars denote standard error

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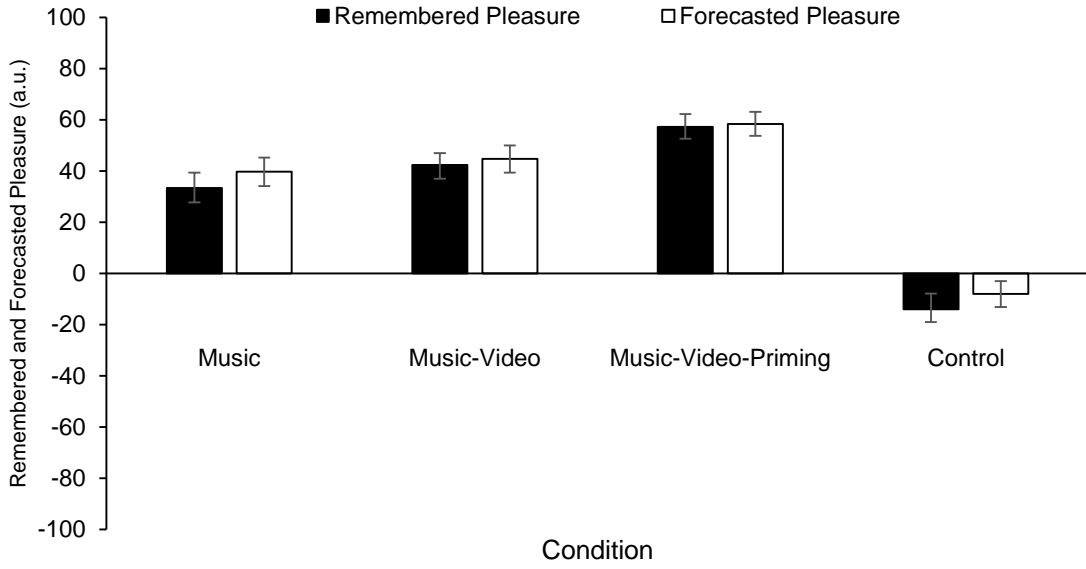


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606 **Fig 2.** Significant condition  $\times$  time interaction for RPE ( $p = .001$ ); error bars denote standard

607 error

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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.