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REGULAR ARTICLE

Mindfulness Versus Distraction to Improve Affective Response and Promote Cardiovascular Exercise Behavior

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Abstract

Background Variation in affective response to exercise partially explains high levels of inactivity. Examining ways to improve affective responses to physical activity is, therefore, an important direction for research aiming to promote exercise behavior.

Purpose This study compares three strategies: mindfulness, distraction, and an associative focus comparison group as potential strategies to improve affective response to exercise and promote exercise behavior.

Methods Seventy-eight insufficiently active individuals (*M* age 26.82, 74% female) were randomly assigned to one of the following three conditions: (a) mindfulness, (b) distraction, or (c) associative attentional focus. The study was divided into two phases, a laboratory session in which participants learned their assigned strategy and completed a 30 min supervised exercise bout and an at-home intervention in which participants used their assigned strategy while exercising on their own for 2 weeks and filled out daily surveys.

Results Seventy-five participants completed the study. The central hypotheses were partially supported. Participants in the mindfulness and distraction conditions maintained more positive affective response to exercise over time compared to participants in the associative focus condition, whose affect became less positive over time (p = .04). Participants in the distraction condition experienced lower perceived exertion during exercise (p = .01). There were no condition differences in self-reported minutes exercised during follow-up, but participants in the mindfulness condition reported exercising for more days during the follow-up compared to the associative focus condition (p = .01).

Conclusions These findings suggest individuals wishing to increase their cardiovascular exercise could engage in mindfulness or distraction in order to make exercise feel less difficult and/or more affectively pleasant.

Keywords: Affective response • Physical activity • Mindfulness • Distraction • Behavior maintenance

The World Health Organization, the U.S. Department of Health and Human Services, and the American College of Sports Medicine (ACSM) recommend that adults aged 18–64 do at minimum 150 min of moderate-intensity aerobic physical activity per week or at least 75 min of vigorous-intensity exercise (or an equivalent combination thereof [1–3]) to prevent a wide range of negative health outcomes [4]. Yet, only half of American adults meet these minimum recommendations [5]. Some of the most common reasons adults cite for not exercising are lack of self-motivation, low self-efficacy for physical activity, lack of self-regulation skills for physical activity, and the fact that they find exercise boring or unenjoyable [6].

Physical Activity and Affect

Simply put, people are more likely to exercise if it feels good while they are doing it. Studies have shown that affective valence measured during a moderate-intensity treadmill walk was associated with minutes per week of physical activity [7] and that increases in positive affect over the course of an exercise bout were associated with more frequent exercise participation at follow-up [8]. A review of existing research in this area suggests that individual differences in the degree to which one

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experiences more positive affect while exercising is consistently related to greater levels of future exercise behavior [9].

Affective response to exercise is strongly determined by exercise intensity such that it tends to be positive during low-to-moderate intensity exercise but, as intensity increases, there is interindividual variability in affective response. Researchers have identified the ventilatory threshold (VT; or the point where the activity becomes more anaerobic than aerobic, i.e., breathing becomes labored and lactic acid accumulates) as the physiological marker of a "turning point" for affective response during exercise. Specifically, affect tends to be positive on average during exercise at intensities below VT but, as intensity approaches VT, there is individual variability in the degree to which affect during exercise is positive versus negative; finally, affective response tends to be nearly universally negative at intensities that exceed VT [10, 11]. These findings suggest that affective responses at exercise intensities near VT may be malleable via intervention [12, 13].

Thus, because (a) there are individual differences in the degree to which people experience exercise near the ventilatory threshold as pleasant versus unpleasant and (b) these affective responses to exercise are a strong predictor of future exercise behavior, research that illuminates ways to help individuals manage, or even decrease, their in-the-moment negative affective responses to moderate-to-vigorous-intensity exercise may help to promote higher levels of exercise behavior. However, studies that attempt to manipulate experienced affect during exercise are, at the current time, scarce [9, 14]. One recent study found that manipulating positive expectancies about exercise-related affect led to more positive experienced affect while exercising [15]. Several studies have also found that listening to music and/or watching music videos is associated with more positive affect while exercising at vigorous intensities compared to control conditions [16–18]. Others have found that exercising outdoors, rather than indoors, was associated with more positive affect during exercise [19, 20]. Further research examining additional ways to change in-task affect during exercise, especially exercise at more vigorous intensities, is needed; in a meta-analysis on the relationship between affective response to exercise and future behavior, Rhodes and Kates note that "interventions with sustained attempts to improve in-task exercise affect… should be an aim of future research" [9].

To address this gap in the literature, this study examines two cognitive strategies to make experienced affect during exercise more positive and, thereby, promote exercise behavior. The first strategy is the practice of mindfulness, a technique in which an individual continuously monitors their present-moment experience, including physical sensations, thoughts, and emotions/affect while maintaining a sense of acceptance and nonjudgment of that experience. The second strategy is distraction, in which the individual consciously directs their attention to something unrelated to the exercise experience in an attempt to disengage from it.

Mindfulness and Exercise

In recent years, the concept of *mindfulness* has been promoted as a strategy for individuals to reduce negative affect across many contexts. Mindfulness is commonly discussed as a state of enhanced attention, awareness, and nonjudging acceptance of one's current experience in the present moment [21]. A large body of research has shown that mindfulness is associated with greater pleasant affect and less unpleasant affect [21]. The literature illuminating the mechanisms through which mindfulness influences affect informs the prediction that being mindful while engaging in physical activity could improve affective response during exercise. Mindfulness has been demonstrated to increase willingness to experience negative sensations and acceptance of discomfort or distress [22], which may help individuals cope with unpleasant sensations that accompany increases in exercise intensity.

Cross-sectional studies have provided initial support for the assertion that mindfulness practice is associated with higher levels of physical activity [23], and meta-analytic work shows small-to-moderate effects of mindfulness on increasing physical activity in obesity interventions [24]. Interventions, such as Acceptance and Commitment Therapy (ACT) [25, 26], that contain components of mindfulness have also been found to increase exercise behavior [27, 28]. In sum, this literature suggests that engaging in mindfulness during exercise may help individuals increase positive affect and decrease negative affect during exercise, which may encourage exercise maintenance.

Attentional Focus and Exercise

Literature on attentional focus during exercise complicates theories about the relationship between mindfulness and enhanced experience of exercise. Attentional focus during exercise was originally described by Morgan and Pollock [29], who studied distance runners. They identified two attentional focus strategies: (a) association, in which the runner focuses attention on bodily sensations, usually related to performance, or (b) dissociation, in which the runner actively and purposefully blocks out sensations related to physical effort (i.e., distraction) [30, 31]. Research in this area typically finds that, while elite athletes on average *perform* better through associative strategies, nonelite or recreational exercisers (i.e., the population for which exercise adherence is arguably most important) benefit from dissociating during exercise. Specifically, recent reviews found that being distracted during exercise was related to improved exercise adherence, greater enjoyment and less boredom, reduced effort perceptions, and more feelings of tranquility and positive mood change [32] and resulted in lower ratings of perceived exertion and, in some cases, improved affect/mood [31].

Theoretical Proposal: Mindfulness Over Distraction

Based on the current synthesis of the literature, it was hypothesized that recommending a mindful approach to exercise behavior may prove to be the best overall strategy to improve affective response to exercise. Mindfulness embodies the beneficial components of both associative and dissociative attentional focus that have been supported in the literature as beneficial to exercisers in some way. The monitoring of sensations in the body involved in both mindfulness and attentional focus has been shown to improve exercise performance. At the same time, the mindfulness approach to viewing ones' bodily experience with acceptance, nonjudgment, and psychological distance aligns partially with a dissociative approach to exercise (in that it involves internal regulation of ones' perception of their immediate sensory experience), which has benefits for nonathletes and leads to greater maintenance of exercise behavior over time [32]. The literature on mindfulness strongly links being mindful with increases in positive affect [21, 22, 33]. While it has not been extensively tested in an exercise context, being mindful during exercise should increase positive affect through the same mechanisms that it does in other contexts. Improving affect during exercise through mindfulness should, directly and indirectly, lead to the maintenance of exercise behavior [7, 34, 35].

The Current Study

Both mindfulness and distraction (dissociative focus) during exercise have potential merits as cognitive strategies to improve affective response during exercise, though, based on the above review and synthesis of the literature, we purport that mindfulness may be the better strategy of the two. No study has directly compared these strategies with one another and examined their effects on psychological response to exercise either acutely or over the longer term.

In a randomized experiment, the current study examined which cognitive strategy better helps individuals manage unpleasant affect associated with exercise. Specifically, we aimed to target our intervention conditions toward a dismantling of the theoretical components of mindfulness as being comprised of (a) attention to the present moment (exercise-related feelings) and (b) nonjudgment/acceptance of the exercise experience (see Fig. 1). The mindfulness condition, clearly, targeted both of these constructs. In contrast, the distraction condition was an attempt to guide participants to, unlike mindfulness, (a) bring their attention *away* from exercise-related feelings, but similar to mindfulness, (b) accept and not judge that experience (because attention to the experience is dampened/removed through distraction). Finally, we compared both of these conditions to an associative focus control condition, which contained the mindfulness component of (a) attention to exercise-related feelings, but in contrast to mindfulness and distraction, (b) encouraged judgment of those feelings. Using this associative focus condition as a comparison group allowed us to provide a full dismantling of the essential components of mindfulness. Further, we speculated that the thought pattern it aims to invoke is reflective of the kinds of cognitions (a focus on physical sensations and a perception of being "slow") that might result in findings that exercise is associated with a less positive affective response for nonregular exercisers (c.f., [34]).

Thus, this study involved random assignment to one of the following three "cognitive strategy" conditions: (a) mindfulness; (b) distraction (no different theoretically from dissociative attentional focus but called distraction hereforth); and (c) associative focus/"self-monitoring". Affective response and perceived exertion were measured during a supervised exercise bout, and exercise behavior was measured during an at-home self-guided intervention. It was hypothesized that participants in both the mindfulness and distraction conditions would report more positive affective valence, lower felt arousal, and lower perceived exertion (RPE) than the associative condition, while participants in the mindfulness condition would report more positive affective valence, lower felt arousal, and lower RPE than those in distraction condition during exercise just below VT. It was further

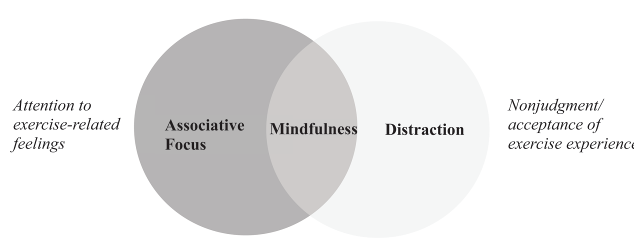

Fig. 1. Conceptual overlap and distinctions between the three study conditions.

hypothesized that participants in the mindfulness and distraction conditions would exercise more than the associative focus condition during the 2 week follow-up.

Methods

Design

This study had two phases. In the first phase, participants came into the lab, completed baseline measures and a fitness test, and were randomly assigned to condition. Acute psychological response to cardiorespiratory exercise was examined before and after participants were trained to utilize their assigned strategy. In the second phase, participants completed a 2 week at-home exercise intervention, involving exercising on their own using their assigned strategy, and reported their exercise behavior via online daily diary measures.

Participants

Seventy-eight participants were recruited from the greater Boulder, Colorado community through flyers, online advertisements, and word-of-mouth. As can be seen in Table 1, participants were 26.8 years of age (SD = 6.62) and 74% were female, and the majority (79.5%) were white. Participants were recruited on the basis of insufficient (less than 150 min/week) cardiovascular exercise for the past 3 months as reported on an online study screening measure. Enrolled participants had engaged in an average of 73.70 min of moderate-intensity exercise (SD = 52.62) per week for the past 3 months. Additional inclusion criteria, as assessed on the screening measure, were that participants were 18–40 years of age, physically capable of and willing to engage in moderate-vigorous-intensity exercise, willing to fill out daily online survey measures for 2 weeks after the intervention, willing to accept random assignment, and had a smartphone or comparable device that could be used to play podcasts (should they be assigned to the distraction condition). Exclusion criteria were health contraindications for safe engagement in moderate-vigorous-intensity exercise (e.g., diabetic, pregnant, and family history of cardiovascular disease) as assessed via the Physical Activity Readiness Questionnaire (PAR-Q) on the online screening measure [36]. Of the 78 participants enrolled in the study, 78 were randomized to condition. One participant in the associative focus condition dropped out of the study part way through the exercise bout due to illness and an additional two participants, one in the mindfulness and one in the distraction condition, did not complete any of the daily survey measures during follow-up, leaving 75 participants for analyses.

Power analysis

Power was estimated using G*Power, based on a within-between repeated-measures analysis comparing group means on repeated measures of psychological constructs (i.e., affect) during the 30 min exercise bout. Power was estimated using standard procedures following Cohen [37]. Power was estimated to detect a small-to-moderate effect (f = .20) with alpha of .05 and power of .95 for the difference between three groups using four repeated measurements during the exercise bout and estimating a correlation of .5 between repeated measures and

Table 1 Demographics and descriptive statistics

	Overall (N = 78) M (SD)	Min	Max	Mindfulness (n = 28) M (SD)	Distraction (n = 23) M (SD)	Self-monitoring (n = 27) M (SD)	Test statistic for condition differences	p
Gender (% female)	74%			81%	70%	60%	$\chi^2(2) = 1.21$	.547
Race/ethnicity (% white)	78%			79%	83%	78%	$\chi^2(8) = 6.44$	.598
Age (years)	26.82 (6.62)	18	40	28.79 (7.56)	25.43(5.32)	25.92 (6.29)	$F_{2,50} = 2.03$	.140
Body mass index (kg/m^2)	24.22 (4.56)	18.16	40.23	23.98 (4.49)	23.48 (4.14)	25.10 (5.23)	$F_{2,51} = 0.80$	.452
Baseline mod-vig intensity exercise minutes[a]	77.70 (52.62)	0	240[2]	74.63 (48.08)	83.04 (51.60)	64.81 (58.04)	$F_{2,51} = 0.75$	.477
Number of follow-up surveys completed	12.06 (3.85)	0	14	13.11 (1.73)	12.13 (3.79)	10.93 (5.11)	$F_{2,75} = 2.29$	.109
Number of withdrawn participants	2			1	1	1		

Table 1 presents descriptive statistics for demographic variables, both overall and by condition.

[a]Moderate-vigorous-intensity exercise minutes were computed by adding reported moderate intensity minutes and 2× reported vigorous-intensity minutes, c.f. [3].

[b]Seven individuals reported more minutes of moderate-vigorous-intensity exercise at the baseline session than they did in the screening measure for the study, where eligibility criteria for the baseline visit included that potential participants were participating in ≤150 min of moderate-vigorous-intensity exercise per week. These participants are still included in all analyses.

nonsphericity correction ε = 1.0. The sample size needed to achieve power of .95 was 69 participants. Seventy-eight participants were enrolled in the study to account for possible attrition.

Procedures

Recruitment

Recruitment materials described the opportunity to participate in a research study examining strategies people can use to change their experience of cardiovascular exercise. The advertisements noted the main eligibility criteria, a summary of the assessments involved in study participation, and the opportunity to earn up to $29 for participation.

Laboratory session

In order to reduce experimenter demand, all study procedures for the laboratory appointment were fully scripted, standardized, and administered by trained research assistants blind to the study's hypotheses. Prerandomization, the same script was used for all participants (for the informed consent, baseline survey, and Talk Test procedures). Postrandomization, the research assistant used a script for the assigned intervention condition. The content of these scripts is available from the first author. At the beginning of the laboratory session, participants completed informed consent. Next, they completed the baseline survey measures on a laboratory computer.

Talk Test

After completing the baseline measures, participants were fitted with a heart rate monitor and then underwent a Talk Test [38] in order to determine an exercise intensity near the participant's VT. The Talk Test has been shown to reliably approximate VT across several studies [38–40]. A masters-level exercise physiologist trained research assistants to administer the Talk Test protocol. After reaching the intensity determined by the Talk Test, participants exercised for 5 min at that intensity and completed baseline measures of subjective response to exercise. At this point, the treadmill was stopped and participants began the intervention.

Randomization and intervention outline

The research assistant consulted a random numbers list to assign the participant to their study condition. All participants were told that their condition was a "technique for improving our emotional response to everyday life experiences that we are examining as a strategy to enhance the experience of exercise." Participants were told that, when people exercise at a moderate-to-vigorous intensity, their internal experience might feel unpleasant and that their assigned strategy would be used to address that feeling.

Next, the skills to be used under each condition were explained. Participants were given specific examples of the types of negative thoughts or feelings that might come up while exercising and told how they might apply their assigned strategy when these thoughts arise. These skills were practiced with a demonstrative exercise, developed for an ACT exercise intervention, and modified for each condition in the current study [41]. Participants were asked to hold their legs out in front of them and not put them down until they were told that they could (about 60 s). The research assistant then guided the participant toward applying their assigned strategy to the experience of holding their legs out as a parallel to negative sensations one might experience during cardiovascular exercise. At the end of this brief intervention, participants were told that they would apply the strategy they just learned while exercising.

Mindfulness condition In the mindfulness condition, participants were told to bring their attention to the present moment while exercising, including noticing how their body feels, focusing on their breathing, or being aware of the thoughts that arise. Participants were told to do their best to experience these sensations and feelings without judging them through the process of observing their thoughts with distance while exercising rather than distracting away from them. They were taught that they could label their thoughts, feelings, and sensations while exercising (e.g., "Part of me is noticing the urge to slow down"). During the "legs up" exercise, participants were guided to notice without judgment their thoughts, sensations, and urges. It was emphasized that having similar negative thoughts and sensations while exercising was normal, but that it does not mean that one has to stop exercising.

Distraction condition In the distraction condition, participants were told that their strategy was to bring their attention *away* from their experience while exercising and that they would be doing so by listening to podcasts while exercising. Podcasts were chosen as a method of distraction for this study because they are portable with a mobile device and, therefore, could be used while exercising both indoors or outdoors (compared, e.g., to watching television), and are free to access. Participants were told that if they begin to feel fatigued during exercise, they should remind themselves to focus on the distraction instead. During the "legs up" demonstration, the research assistant played a song on a study iPod and told the participant to pay attention to the song and focus their attention away from the experience of holding out their legs. Participants were then asked to choose from one of three preselected podcast episodes on the study iPod to listen to while exercising.

Associative focus condition Participants were told that the name of the strategy for the associative focus condition was "self-monitoring." Similar to the mindfulness condition, participants in this condition were told to bring their attention to their experience while exercising. However, in this condition, participants were encouraged to immerse themselves in their affective experience rather than simply observe the experience. Participants were told to "turn up [their] internal monologue of sensations and desires" while exercising, including saying to themselves "I want to stop" or "My legs are burning" if fatigue sets in during exercise.

Exercise bout

Once participants finished learning their assigned intervention, they began the 30 min exercise bout. Participants warmed up on the treadmill until they reached the heart rate that was determined during the Talk Test. The point at which they reached this heart rate was designated as minute 0 and the 30 min timing began. Participants' heart rates were observed by the research assistant during the bout, and speed and incline were adjusted if needed to ensure that their heart rates remained in the prescribed range. After participants were finished cooling down from the exercise session, they completed the manipulation check items.

Explanation of 2 week intervention

The laboratory session ended with an explanation of the 2 week self-administered exercise "assignment." Participants were all given the same instructions, except those specific to their condition assignment. Participants were told that they should try to exercise at least 150 min per week for the next 2 weeks because it represents national guidelines for minimum cardiovascular exercise engagement. Participants were told to try and exercise at the same intensity as they did during their exercise session in the lab. To keep their form of exercise consistent with their supervised exercise session in the lab, participants were told that they should walk, jog, run, or hike as exercise. Participants in the mindfulness and associative focus conditions were told to avoid distractions like music, podcasts, or television while exercising, while participants in the distraction condition were told to listen to a podcast every time they exercised for the next 2 weeks.

2 week intervention period

During the 2 week intervention, at 6 AM each morning, participants were sent a short email with a reminder and tip about using their assigned strategy if they exercise that day. This email also included a link to the daily survey measure and instructions to fill it out at the end of the day, whether they exercised or not. All study procedures were approved by the relevant institutional review board.

Measures

Baseline survey measures

Study data were collected and managed using REDCap electronic data capture tools hosted at the institution where this research was conducted [42]. Participants completed the following measures via REDCap at baseline. Demographics: participants reported their gender, age, height and weight, ethnicity, race, relationship status, level of education, employment status, and income. Frequency of exercise behavior: participants completed The Godin Leisure-Time Exercise Questionnaire (GLTEQ) [43], a self-report assessment of the quantity, frequency, and intensity of exercise participation for an average week. Participants reported both the number of exercise sessions per week and minutes per week of mild-, moderate-, and vigorous-intensity exercise.

Acute exercise measures

Participants first responded to the measures described below during the Talk Test. During the experimental exercise bout, participants responded to these measures at 10 min intervals: at 0 (i.e., when participants reached the appropriate heart rate range after the warm-up and 30 min timing began), 10, 20, and 30 min. For the baseline measure at the conclusion of the Talk Test, participants rated how they felt in the past 5 min. For the experimental bout, participants rated how they felt in the past 10 min. Feeling Scale (FS): the FS [44] was used to measure affective valence during exercise [11, 45]. Participants were asked to "Please choose the number that best describes how you were feeling on average in the past (five/ten) minutes." This single item, 11-point measure ranges from −5 to + 5 (+5 = very good, 3 = good, 1 = fairly good, 0 = neutral, −1 = fairly bad, −3 = bad, −5 = very bad). Felt Arousal Scale (FAS): the FAS was used to measure affective arousal during exercise [11, 45]. Participants were asked to "Please indicate how aroused ("worked up") you felt on average in the past (five/ten) minutes." This single item measure ranges from 1 to 6 (1 = low arousal, 6 = high arousal) [46]. Rate of Perceived Exertion (RPE): lastly, participants were asked to "Please rate the average intensity of the past five/ten minutes." Ratings were reported on a scale from 6 (no exertion) to 20 (maximal exertion) from Borg [47].

Supervised exercise manipulation check

After the supervised exercise session, participants self-reported their agreement with the statements, "I observed the exercise experience closely"; "I paid close attention to the physical sensations caused by exercise"; "I tried to stay focused on something other than my exercise experience"; and "I concentrated on other things rather than the exercise experience" on a 7-point Likert scale from 1 (Never did that) to 7 (Always did that). These items were adapted from Arch et al. [48].

Daily exercise diary measures

For the 14 days following the baseline appointment, participants were first asked if they exercised that day. If participants did not exercise that day, then the survey ended. If participants did exercise that day, they were asked how many minutes they exercised, and what type of exercise they did.

Results

Talk Test and Baseline Affect

The average heart rate range determined by the Talk Test was 145.1 beats per minute (bpm; *SD* = 19.52). Predicted maximum heart rate for the average age in the sample is 193.2 bpm (using the formula 220-age to estimate maximum heart rate), and moderate-intensity exercise corresponds to 50%–70% of maximum heart rate or 96.6–135.2 bpm, while vigorous-intensity exercise corresponds to 70%–80% of maximum heart rate or 135.2 to 154.56 bpm [49]. Thus, the Talk Test-determined heart rate corresponded to, on average, a vigorous-intensity exercise intensity for most participants. However, given the substantial variability in heart rate across participants, heart rate is included as a covariate in analyses as the goal of this study was to examine variation in *subjective* response to physical activity as the result of the manipulations, *holding objective intensity constant*. There were no significant differences in Talk Test heart rate by condition, $F_{2,74} = 0.80$, $p = .45$ and no significant condition differences were observed in the subjective response measures (FS, FAS, and RPE) measured during the Talk Test (FS: $F_{2,74} = 0.64$, $p = .38$, FAS: $F_{2,74} = 0.24$, $p = .79$, RPE: $F_{2,74} = 0.88$, $p = .42$). Thus, random assignment was successful with regard to these measures.

Manipulation Check

An average for the first two items of the manipulation check was computed to create an average "observed" score, where higher scores represent greater attention to the feelings and sensations caused by exercise. The second two items of the manipulation check were averaged to create a "distracted" score, where higher scores represent attention to something other than exercise. Differences in these two averages by condition were examined in two one-way analysis of variances. As expected, participants in the mindfulness and associative focus conditions reported that they observed the exercise experience significantly more, $t(74) = 7.67$, $p < .001$, and were distracted significantly less, $t(74) = -9.65$, $p < .001$, than those in the distraction condition.

Acute Exercise Response During Laboratory Session

Analyses to examine the effect of the three conditions on affect, arousal, and RPE during the laboratory exercise bout involved one within-subjects factor (time: four repeated measures of affect, arousal, or RPE within each session) and one between-subjects factor (condition). Condition was contrast coded to compare (a) the mindfulness and distraction conditions to the associative focus condition and (b) the mindfulness and distraction groups to each other. As noted above, heart rate (mean centered) during the exercise session was included as a covariate. Means for FS, FAS, and RPE at each time point are presented in Fig. 2.

Affective valence: FS

In the mixed-effects model predicting FS scores, the contrast comparing the mindfulness and distraction conditions to the associative focus condition was significant, $t(73) = 2.93$, $p = .004$, such that affective valence was more positive in the mindfulness and distraction conditions compared to the associative focus condition. The mindfulness and distraction conditions were not significantly different from each other, $t(73) = -0.37$, $p = .71$. There was a significant condition by time interaction: the linear slope of affect was more positive in the mindfulness and distraction conditions compared to the associative focus condition, $t(74) = 2.06$, $p = .043$. When examining simple linear effects by condition, affect significantly decreased over time in the associative focus condition, $t(74) = -2.5$, $p = .02$, but not in the mindfulness nor distraction conditions (see Fig. 2a). The effect of heart rate was significant in this model such that, as heart rate increased, affect was more negative, $t(73) = 2.03$, $p = .046$.

Affective arousal: FAS

Linear and quadratic effects of time were observed such that arousal increased over the course of the bout, $t(74) = 5.79$, $p < .001$; this linear increase was qualified by a significant quadratic effect such that arousal was higher in the middle of the bout, $t(74) = 4.32$, $p < .001$. There were no significant effects of condition or the covariate (see Fig. 2b).

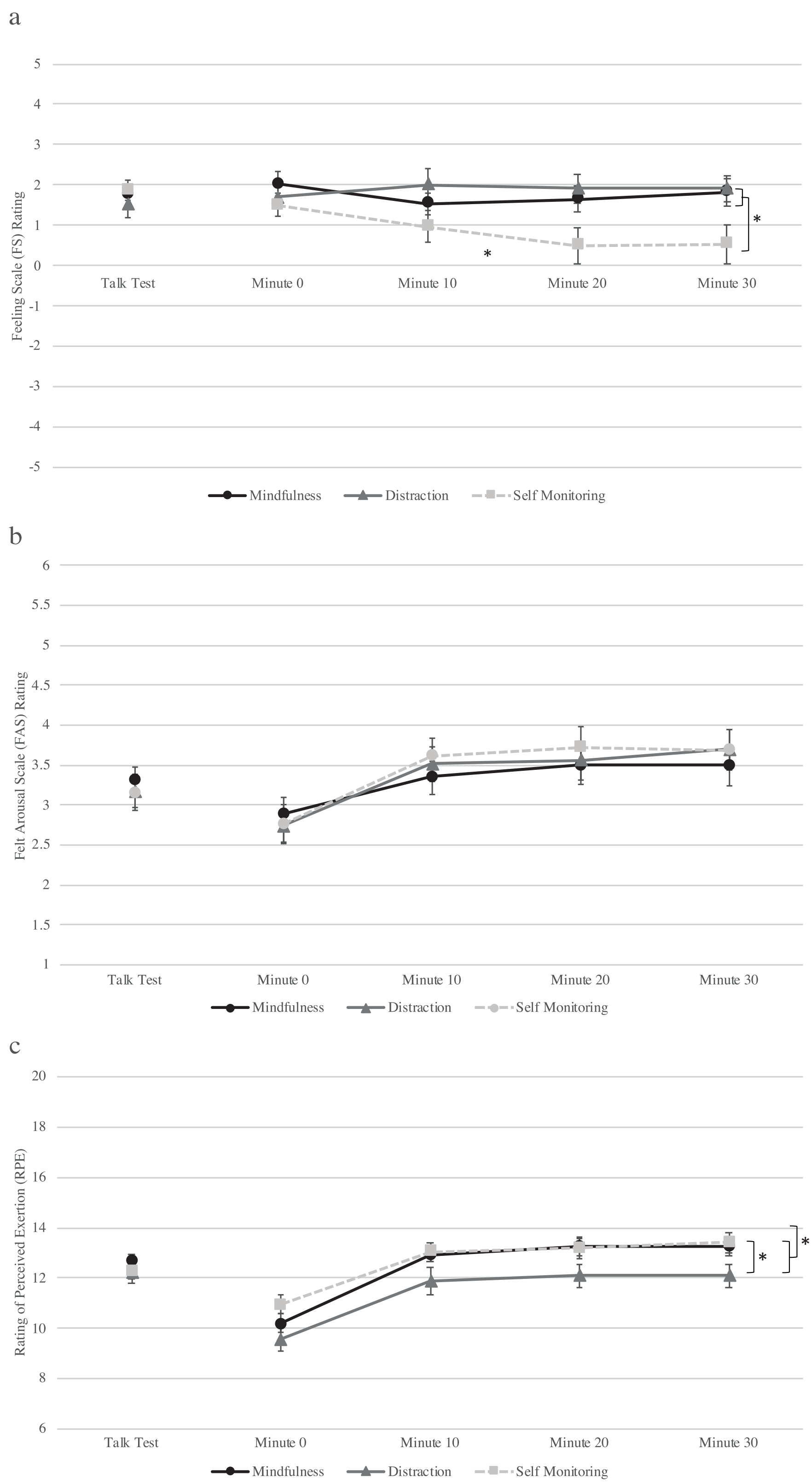

Fig. 2. Subjective response to exercise by condition. Means for the Feeling Scale (FS; 1a), Felt Arousal Scale (FAS; 1b), and Rating of Perceived Exertion (RPE; 1c) are presented by condition with standard error bars. The Feeling Scale ratings can range from −5 to +5; the FAS can range from 1 to 6; the RPE scale ranges from 6 to 20. Talk Test time point represents ratings before participants were assigned to condition. Asterisks denote significant differences described in text.

Rate of Perceived Exertion

The mixed-effects model for RPE also controls for heart rate; thus, it models changes in *perceived* or *subjective* exercise intensity while controlling for *objective* intensity of exercise. Significant linear and quadratic effects of time were observed such that RPE increased significantly over the course of the 30 min exercise bout, $t(74) = 9.37$, $p < .001$, and this increase was larger from the beginning to the middle of the bout, $t(74) = 8.22$, $p < .001$. Significant condition differences in perceived exertion were also observed. The contrast comparing the mindfulness and distraction groups to the associative focus group was significant, $t(73) = -2.8$, $p = .006$, although this difference seems to have been driven by the lower average RPE in the distraction group relative to the other two groups. The contrast comparing the mindfulness to the distraction group was also significant such that perceived exertion was higher in the mindfulness group compared to the distraction group, $t(73) = 2.6$, $p = .01$. No significant Condition × Time interactions were observed in this model. As expected, heart rate significantly predicted RPE such that higher heart rate was associated with greater RPE, $t(73) = 4.82$, $p < .001$ (see Fig. 2c).

Response Over the 2 Week Intervention: Exercise Frequency and Quantity

The second phase of the study assessed the longer-term effect of the three conditions on exercise volume during the 2 week at-home exercise intervention. Mixed-effects models were used to address this aim, with exercise volume and frequency as dependent variables, including a within-subjects factor coding the linear day effect and between-subjects contrasts (as above) coding condition. All participants who completed at least some of the daily measures ($N = 75$) were included in analyses. If a participant did not complete the survey on a particular day, it was conservatively assumed that the participant had not exercised that day and their behavior was coded as 0 (*M* nonresponse days per participant: mindfulness group = 0.93, distraction group = 1.36, associative focus group = 2.12, $F_{2,72} = 1.10$, $p = .34$). Participants reported running 9% of the time, jogging 22% of the time, walking 45% of the time, hiking 7% of the time, and another form of exercise 18% of the time. Exercise sessions that were not running, jogging, walking, or hiking (per instructions to participants) were excluded from analyses; when these sessions were included, the pattern of results did not change.

The primary follow-up outcome of interest was the number of minutes participants reported exercising during the 2 week exercise intervention. In the linear mixed effects model with minutes of exercise as a dependent variable, the number of self-reported minutes did not increase significantly over time. There were no significant condition differences in the average minutes reported (mindfulness vs. associative focus comparison, $t[72.82] = 1.63$, $p = .11$), although at a mean level, the mindfulness condition ($M = 155.33$, $SD = 115.95$) reported exercising more minutes than the distraction ($M = 117.85$, $SD = 81.29$) and associative focus ($M = 110.84$, $SD = 92.60$) conditions (Cohen's *d*: mindfulness vs. distraction = 0.37, mindfulness vs. associative focus = 0.43, distraction vs. associative focus = 0.08; when "other" forms of exercise were included, the means for condition minutes were: mindfulness condition $M = 172.28$, $SD = 104.86$; distraction condition $M = 163.5$, $SD = 150.21$; associative focus condition $M = 139.32$, $SD = 97.80$). There were no significant Condition × Time interactions. On average, across condition and time, the model estimated intercept for minutes exercised per day was 18.43 min, corresponding to 129 min per week.

While the instructions given to participants were to exercise for at least 150 min per week and did not specify frequency of exercise to reach that number, given the mean level differences we observed in this variable, we were also interested in exploring whether the total number of exercise sessions differed across participants. Thus, an exploratory outcome of interest was the frequency of exercise behavior over the 2 week at-home exercise intervention. This dependent variable was coded as 0 if the participant did not exercise and 1 if the participant did exercise on a particular day. This outcome variable was examined as a function of condition and linear day using a mixed effects logistic regression model. Participants in the mindfulness ($M = 6.78$ days, $SD = 3.41$) and distraction ($M = 5.5$ days, $SD = 3.92$) conditions reported exercising significantly more often than those in the associative focus condition ($M = 4.2$ days, $SD = 3.42$), $z = 2.32$, $p = .02$. There was no difference in exercise frequency between the mindfulness and distraction conditions, $z = 1.25$, $p = .21$. Pairwise differences demonstrated that participants in the mindfulness condition were more likely to exercise on a given day than participants in the associative focus condition, $z = 2.72$, $p = .01$, but that the distraction condition was not different from the associative focus condition, $z = 1.35$, $p = .17$. Condition × Time interactions were not significant.

Discussion

This study examined strategies to improve subjective responses to moderate-to-vigorous-intensity exercise and to help individuals increase and maintain their cardiovascular exercise behavior over the long term. Mindfulness and distraction were compared to an associative "self-monitoring" condition. It was hypothesized that both mindfulness and distraction would improve subjective response to exercise (both during the acute exercise bout and over the long term) relative to associative focus but that the mindfulness group would have better subjective response to exercise, as well as more exercise behavior during the 2 week intervention, compared to the distraction group. Consistent with hypotheses, participants in the mindfulness and distraction groups maintained a higher level of positive affect during the laboratory exercise bout relative to the associative focus group, which significantly decreased in affect over the course of the bout. However, contrary to hypothesis, the mindfulness group did not have significantly more positive affect compared to the distraction group, nor did the three groups differ in arousal during the bout. In partial support of hypotheses, the distraction group reported lower perceived exertion compared to both the mindfulness and associative focus groups.

While these outcomes were in some ways contrary to the hypothesis that mindfulness would lead to the most positive subjective response to exercise, it is not surprising that distraction was an effective technique to improve subjective response as this has been previously demonstrated in the literature [32]. Additionally, it is noteworthy that mindfulness led to greater stability of positive affect during exercise compared to associative focus, yet these conditions did not differ in their perceived exertion. This suggests that the key aspects of mindfulness involving acceptance and nonjudgment of the present moment experience might help individuals reappraise or tolerate the discomfort associated with exercise and, thus, experience it as less emotionally or affectively negative even if it feels difficult.

The second set of hypotheses concerned the longer-term effects of the three strategies. For the primary outcome, the number of minutes participants reported exercising, there were no observed significant differences across conditions, contrary to hypotheses. In partial support of hypotheses, the exploratory outcome, frequency of exercise, showed that participants in the mindfulness and distraction conditions reported exercising more times during the 2 week follow-up than participants in the associative focus condition. Examining these differences pairwise, participants in the mindfulness condition reported they exercised significantly more frequently than those in the associative focus condition, while the reported frequency of exercise was not significantly different between the distraction and associative focus conditions.

Participants in the mindfulness and distraction conditions reported that they exercised most frequently, and participants in the mindfulness condition reported exercising the most number of days overall. This was consistent with expectations as it was theorized that mindfulness might be a useful strategy to use during exercise over the long term. However, there were no significant condition differences in self-reported minutes of exercise during the follow-up, though we note that participants in the mindfulness condition exercised for more minutes on average than those in the other two conditions. This could be explained by the fact that participants were given a specific goal to meet for their exercise behavior (150 min per week, minimum) and that participants, regardless of condition, may have striven to meet that goal but not to exceed it.

In sum, when comparing mindfulness to distraction and associative focus as strategies to improve subjective response to exercise, the evidence suggested that both mindfulness and distraction may be effective strategies to improve subjective response to exercise behavior. Both mindfulness and distraction had similar effects on affective valence during exercise. Distraction also appeared to reduce effort perceptions over time. Perhaps this additional "benefit" of distraction reducing perceived effort may lead to the conclusion that distraction is the best strategy overall. Yet increased perceptions of effort in the mindfulness condition did not seem to translate to a more negative affective response (compared to distraction). Thus, mindfulness may be similarly beneficial to affect, even if effort perception is higher. Given the increased popularity and general public interest in mindfulness in recent years, as well as technological advances that allow for a variety of accessible distractions individuals can use during exercise (e.g., television streaming services, virtual reality, and exercise games in mobile applications [50]), these results suggest that it may be effective to recommend *both* mindfulness and distraction as ways to manage negative affect during moderate-to-vigorous exercise.

Strengths and Future Directions

This study has several strengths. First, this is the first study that the authors know of that compares multiple cognitive strategies to improve affective response during exercise, selected for theoretically driven reasons, to one another directly. This was done in the context of strong study design, utilizing random assignment to condition and comparing the two conditions of interest (mindfulness and distraction) to an associative focus group. The research assistants who interacted with participants were blind to the study hypotheses, reducing experimenter demand characteristics. Interventions were designed to be both relevant to the study population and scalable—for example, in the distraction condition, participants listened to podcasts, which are easily accessible and free to anyone with a smartphone or a similar portable device. Finally, the study population was made up of individuals for whom the research questions are most relevant—since the ultimate goal of this research program is to find strategies to promote increased exercise behavior, testing hypotheses among individuals who were currently insufficiently active was critical.

In terms of future directions, it is clearly important to examine whether these strategies work over periods of time longer than 2 weeks. This is relevant to one of the potential theoretical moderators of the effectiveness of these strategies—exercise experience. For example, one hypothesis might be that distraction is a useful strategy to use when initiating an exercise routine but, in terms of longer-term maintenance (>2 weeks), mindfulness may help individuals continue exercise over the long term. The novelty of distraction during exercise might wear off after a few weeks, and strategies such as mindfulness might become more important and effective later in the process of exercise maintenance. On the other hand, it is equally possible that distraction techniques have greater mass appeal than mindfulness as they are simpler to engage in and are easier to understand and communicate conceptually. Future studies should also examine additional moderators of these effects. For example, at especially high intensities of exercise, research shows that maintaining thoughts unrelated to exercise (e.g., focus on a distraction) might not be possible [51]. Perhaps mindfulness would be more effective under those circumstances.

Limitations

One major limitation is the demographic makeup of the sample. A more diverse sample with regard to race, age, and economic background would be necessary for improving the generalizability of these results. Due to limited resources, we were unable to use a VO_2 max test to estimate VT and so used the Talk Test procedure instead. Based on heart rate ranges determined by this procedure, the Talk Test estimated a moderate-to-vigorous-intensity of exercise on average. However, the relative subjectivity of this method to determine exercise intensity meant that the intensities participants exercised at ranged from the lower end of moderate intensity to the higher end of vigorous intensity. While heart rate was statistically controlled in analyses, tighter control of exercise intensity may have allowed us to better observe the subjective effects of the manipulations. The self-report nature of the 2 week exercise intervention is another limitation of this study. Again, given resource restrictions, obtaining an objective measure (i.e., step count or heart rate monitor data) was not feasible.

Another potential limitation of this paper is the fact that the associative focus comparison condition may have decreased affective response more than would be expected under a no-intervention control, leading to a larger difference between the mindfulness/distraction conditions and this condition. While this may be a fair point, we argue, with support from the associative/dissociative focus literature, that focusing one's attention on effort-related somatic cues (and the resulting cognitive appraisals) may be a "default" state for most individuals engaging in moderate-to-vigorous-intensity cardiovascular exercise and a thought pattern recreational exercisers typically attempt to disengage from [52]. Without prescribing a specific associative strategy, we would not know if participants were engaging in their own forms of distraction (e.g., daydreaming) or mindfulness, creating less distinction between our conditions. Second, the affective response literature demonstrates that it is common for nonregular exercisers, such as the current sample, to experience negative affect during exercise [34]; thus, we believe that it is not unexpected that affective response would be relatively more negative in this condition, given no strategy to mitigate that negative affective response.

A final set of potential limitations regards the acute measurements of exercise behavior. The acute measurements of exercise behavior during the study session asked participants to rate how they felt in the past 5/10 min of exercise. These measures were originally designed as state measures and, therefore, asking about their experience in the past 5/10 min may introduce measurement error or create difficulty in making comparisons between this study and others. However, a meta-analysis by Rhodes et al. [14] found that measures of affective judgments during exercise seem to be highly robust to a variety of methods used to assess it; thus, this is unlikely to be a major limitation of the study. Second, the measure of RPE asked participants to "please rate the average intensity of the past five/ten minutes," which departs from recent recommendations that subjective effort be defined in detail to participants before measuring RPE [53]; thus, it is possible that participants may not have clearly understood the construct they were responding to for this measure.

Summary and Conclusions

Half of American adults are insufficiently physically active [5], and variation in affective response to exercise may partially explain levels of inactivity [7, 8, 14]. This study demonstrated that both mindfulness and distraction during exercise lead to improved subjective response to exercise behavior and were associated with more frequent exercise behavior during a brief follow-up. As more positive affective response to exercise is associated with greater maintenance over the long term, individuals wishing to increase their cardiovascular exercise behavior would likely do well to either engage in mindfulness, or find a method of distracting themselves while exercising, to make the experience more affectively pleasant and/or less subjectively difficult. Similarly, health providers hoping to motivate insufficiently active individuals to increase their exercise might wish to recommend mindfulness or distraction as techniques to use while exercising.

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Compliance with Ethical Standards

Authors' Statement of Conflict of Interest and Adherence to Ethical Standards The authors declare that they have no conflict of interest.

Authors' Contributions ASG conceived of and designed the study, trained research assistants, collected and analyzed the data, drafted the manuscript, and approved the final version. ADB provided critical feedback during study conception and design, critically revised the manuscript, and approved the final version.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

References

1. *Physical Activity Fact Sheet*. World Health Organization. Available at https://www.who.int/news-room/fact-sheets/detail/physical-activity. Accessibility verified February 24, 2017.
2. Garber CE, Blissmer B, Deschenes MR, et al.; American College of Sports Medicine. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc.* 2011;43:1334–1359.
3. Piercy KL, Troiano RP, Ballard RM, et al. The physical activity guidelines for Americans. *JAMA*. 2018;320:2020–2028.
4. Warburton DE, Nicol CW, Bredin SS. Health benefits of physical activity: the evidence. *CMAJ.* 2006;174:801–809.
5. Centers for Disease Control and Prevention. National center for chronic disease prevention and health promotion, division of nutrition, physical activity, and obesity: data, trends and maps [online]. 2015. Available at https://www.cdc.gov/nccdphp/dnpao/data-trends-maps/index.html. Accessibility verified November 10, 2018.
6. Sallis JF, Hovell MF. Determinants of exercise behavior. *Exerc Sport Sci Rev.* 1990;18:307–330.
7. Williams DM, Dunsiger S, Jennings EG, Marcus BH. Does affective valence during and immediately following a 10-min walk predict concurrent and future physical activity? *Ann Behav Med.* 2012;44:43–51.
8. Kwan BM, Bryan A. In-task and post-task affective response to exercise: translating exercise intentions into behaviour. *Br J Health Psychol.* 2010;15:115–131.
9. Rhodes RE, Kates A. Can the affective response to exercise predict future motives and physical activity behavior? A systematic review of published evidence. *Ann Behav Med.* 2015;49:715–731.
10. Ekkekakis P, Hargreaves E, Parfitt G. Invited guest editorial: envisioning the next fifty years of research on the exercise–affect relationship. *Psychol Sport Exerc*. 2013;14:751–758.
11. Ekkekakis P, Parfitt G, Petruzzello SJ. The pleasure and displeasure people feel when they exercise at different intensities: Decennial update and progress towards a tripartite rationale for exercise intensity prescription. *Sports Med.* 2011;41:641–671.
12. Ekkekakis P, Hall EE, Petruzzello SJ. The relationship between exercise intensity and affective responses demystified: To crack the 40-year-old nut, replace the 40-year-old nutcracker! *Ann Behav Med.* 2008;35:136–149.
13. Welch AS, Hulley A, Beauchamp M. Affect and self-efficacy responses during moderate-intensity exercise among low-active women: The effect of cognitive appraisal. *J Sport Exerc Psychol.* 2010;32:154–175.
14. Rhodes RE, Fiala B, Conner M. A review and meta-analysis of affective judgments and physical activity in adult populations. *Ann Behav Med.* 2009;38:180–204.
15. Kwan BM, Stevens CJ, Bryan AD. What to expect when you're exercising: an experimental test of the anticipated affect-exercise relationship. *Health Psychol.* 2017;36:309–319.
16. Hutchinson JC, Karageorghis CI, Jones L. See hear: psychological effects of music and music-video during treadmill running. *Ann Behav Med.* 2015;49:199–211.
17. Bird JM, Hall J, Arnold R, Karageorghis CI, Hussein A. Effects of music and music-video on core affect during exercise at the lactate threshold. *Psychol Music*. 2016;44:1471–1487.
18. Jones L, Karageorghis CI, Ekkekakis P. Can high-intensity exercise be more pleasant?: Attentional dissociation using music and video. *J Sport Exerc Psychol.* 2014;36:528–541.
19. Focht BC. Brief walks in outdoor and laboratory environments: Effects on affective responses, enjoyment, and intentions to walk for exercise. *Res Q Exerc Sport.* 2009;80:611–620.
20. Lacharité-Lemieux M, Brunelle JP, Dionne IJ. Adherence to exercise and affective responses: Comparison between outdoor and indoor training. *Menopause.* 2015;22:731–740.
21. Brown KW, Ryan RM. The benefits of being present: Mindfulness and its role in psychological well-being. *J Pers Soc Psychol.* 2003;84:822–848.
22. Arch JJ, Craske MG. Mechanisms of mindfulness: Emotion regulation following a focused breathing induction. *Behav Res Ther.* 2006;44:1849–1858.
23. Strowger M, Kiken LG, Ramcharran K. Mindfulness meditation and physical activity: Evidence from 2012 National Health Interview Survey. *Health Psychol.* 2018;37:924–928.
24. Ruffault A, Czernichow S, Hagger MS, et al. The effects of mindfulness training on weight-loss and health-related behaviours in adults with overweight and obesity: A systematic review and meta-analysis. *Obes Res Clin Pract.* 2017;11:90–111.
25. Hayes SC. Acceptance and Commitment Therapy, relational frame theory, and the third wave of behavioral and cognitive therapies. *Behav Ther.* 2004;35:639–665.
26. Hayes SC, Luoma JB, Bond FW, Masuda A, Lillis J. Acceptance and commitment therapy: Model, processes and outcomes. *Behav Res Ther.* 2006;44:1–25.

27. Butryn ML, Forman E, Hoffman K, Shaw J, Juarascio A. A pilot study of acceptance and commitment therapy for promotion of physical activity. *J Phys Act Health.* 2011;8:516–522.
28. Ivanova E, Yaakoba-Zohar N, Jensen D, Cassoff J, Knäuper B. Acceptance and commitment therapy and implementation intentions increase exercise enjoyment and long-term exercise behavior among low-active women. *Curr Psychol.* 2016; 35:108–114.
29. Morgan WP, Pollock ML. Psychologic characterization of the elite distance runner. *Ann N Y Acad Sci.* 1977;301:382–403.
30. Morgan WP, Pollock ML. Psychologic characterization of the elite distance runner. *Ann N Y Acad Sci.* 1977;301:382–403.
31. Lind E, Welch AS, Ekkekakis P. Do "mind over muscle" strategies work? Examining the effects of attentional association and dissociation on exertional, affective and physiological responses to exercise. *Sports Med.* 2009;39:743–764.
32. Brick N, MacIntyre T, Campbell M. Attentional focus in endurance activity: New paradigms and future directions. *Int Rev Sport Exerc Psychol*. 2014;7:106–134.
33. Brown KW, Ryan RM, Creswell JD. Mindfulness: Theoretical foundations and evidence for its salutary effects. *Psychol Inq*. 2007;18:211–237.
34. Magnan RE, Kwan BM, Bryan AD. Effects of current physical activity on affective response to exercise: Physical and social-cognitive mechanisms. *Psychol Health.* 2013;28:418–433.
35. Kwan BM, Bryan AD. Affective response to exercise as a component of exercise motivation: attitudes, norms, self-efficacy, and temporal stability of intentions. *Psychol Sport Exerc.* 2010;11:71–79.
36. Thomas S, Reading J, Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). *Can J Sport Sci.* 1992;17:338–345.
37. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale, NJ: Erlbaum; 1988.
38. Foster C, Porcari JP, Anderson J, et al. The talk test as a marker of exercise training intensity. *J Cardiopulm Rehabil Prev.* 2008;28:24–30; quiz 31.
39. Persinger R, Foster C, Gibson M, Fater DC, Porcari JP. Consistency of the talk test for exercise prescription. *Med Sci Sports Exerc.* 2004;36:1632–1636.
40. Woltmann ML, Foster C, Porcari JP, et al. Evidence that the talk test can be used to regulate exercise intensity. *J Strength Cond Res.* 2015;29:1248–1254.
41. Stevens CJ. *Get ACTive! A Randomized Controlled Trial of the Feasbility and Effectiveness of an Acceptance-Based Behavioral Intervention to Promote Exercise Adoption and Maintenance*. Psychology and Neuroscience Graduate Theses & Dissertations. 2017;116. Available at https://scholar.colorado.edu/psyc_gradetds/116.
42. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform.* 2009;42:377–381.
43. Godin G, Shephard RJ. A simple method to assess exercise behavior in the community. *Can J Appl Sport Sci.* 1985;10:141–146.
44. Hardy C, Rejeski WJ. Not what, but how one feels: The measurement of affect during exercise. *J Sport Exerc Psychol.* 1989;11:304–317.
45. Russell JA, Barrett LF. Core affect, prototypical emotional episodes, and other things called emotion: dissecting the elephant. *J Pers Soc Psychol.* 1999;76:805–819.
46. Svebak S, Murgatroyd S. Metamotivational dominance: A multimethod validation of reversal theory constructs. *J Pers Soc Psychol*. 1985;48:107.
47. Borg GA. Perceived exertion: A note on "history" and methods. *Med Sci Sports.* 1973;5:90–93.
48. Arch JJ, Brown KW, Goodman RJ, Della Porta MD, Kiken LG, Tillman S. Enjoying food without caloric cost: the impact of brief mindfulness on laboratory eating outcomes. *Behav Res Ther.* 2016;79:23–34.
49. CDC. Target Heart Rate and Estimated Maximum Heart Rate—Physical Activity. 2015. Available at https://www.cdc.gov/physicalactivity/basics/measuring/heartrate.htm. Accessibility verified March 18, 2018.
50. Gillman A, Bryan AD. Effects of performance versus game-based mobile applications on response to exercise. *Ann Behav Med*. 2015; 50:157–162.
51. Balagué N, Hristovski R, Garcia S, Aragonés D, Razon S, Tenenbaum G. Intentional thought dynamics during exercise performed until volitional exhaustion. *J Sports Sci.* 2015;33:48–57.
52. Salmon P, Hanneman S, Harwood B. Associative/dissociative cognitive strategies in sustained physical activity: literature review and proposal for a mindfulness-based conceptual model. *Sport Psychol*. 2010;24:127–156.
53. Pageaux B. Perception of effort in exercise science: Definition, measurement and perspectives. *Eur J Sport Sci.* 2016;16:885–894.