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ABSTRACT

Purpose: Increasing physical activity among adolescents is a public health priority. Because people are motivated to engage in activities that make them feel good, this study examined predictors of adolescents' feelings during exercise. **Method**: During the 1st semester of the school year, we assessed 6th-grade students' ($N = 136$) cognitive appraisals of the importance of exercise. Participants also reported their affect during a cardiovascular fitness test and recalled their affect during the fitness test later that semester. During the 2nd semester, the same participants rated their affect during a moderate-intensity exercise task. **Results**: Affect reported during the moderate-intensity exercise task was predicted by cognitive appraisals of the importance of exercise and by misremembering affect during the fitness test as more positive than it actually was. This memory bias mediated the association between appraising exercise as important and experiencing a positive change in affect during the moderate-intensity exercise task. **Conclusion**: These findings highlight the roles of both cognitive appraisals and memory as factors that may influence affect during exercise. Future work should explore whether affect during exercise can be modified by targeting appraisals and memories related to exercise experiences.

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Lack of exercise threatens people's health. Physical inactivity is the fourth leading risk factor for death worldwide and has been linked to obesity and chronic diseases including cardiovascular disease and Type 2 diabetes (Lee et al., 2012). Most adolescents in the United States do not meet national guidelines for physical activity, and during the past 30 years, obesity among adolescents has nearly quadrupled (Fakhouri et al., 2014). Moreover, physical activity declines in adolescence compared with childhood, and physical inactivity during adolescence predicts inactivity in adulthood (Anderssen et al., 1996). Thus, increasing physical activity among adolescents is a public health priority, and identifying interventions that promote a more active lifestyle can offer great health benefits (Sirard & Barr-Anderson, 2008).

People pursue activities that make them feel good. Positive affect predicts participation in physical activity for children (Schneider, Dunn, & Cooper, 2009) and adults (Hagberg, Lindahl, Nyberg, & Hellénius, 2009), but less is known about factors that promote positive feelings. The current research investigated predictors of adolescents' affective experience during exercise. Based on cognitive appraisal theories of emotion (e.g., Siemer, Mauss, & Gross, 2007), we identified two cognitive processes that we expected to predict adolescents' affective experience during exercise: appraisals of the importance of exercise and bias in memories of past exercise.

Cognitive Appraisals and Affective Experience during Exercise

According to cognitive appraisal theories of emotion, people experience an affective response to events when they appraise those events as relevant to their goals or well-being (Siemer et al., 2007). The quality and intensity of affect experienced depends not just on external properties of events, but on how those events are interpreted or appraised by the individual. As a result, affective responses to the same event can vary dramatically from person to person. Events appraised as conducive to goals evoke positive affect, whereas events appraised as obstructing goals evoke negative affect. The appraised importance of the event for the person's goals influences the intensity of positive or negative affect experienced (Siemer et al., 2007; Sonnemans & Frijda, 1995). One type of appraisal that has been linked to positive affect during exercise is people's beliefs about exercise self-efficacy (e.g., Bozoian, Rejeski, & McAuley, 1994), but people's appraisals of the

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importance of exercise may also predict how they feel. Specifically, appraising exercise as important for attaining the goals of health and well-being may motivate adolescents to reframe potentially aversive physiological cues in a positive manner—for example, as "being good for one's health" or "increasing one's strength" (Magnan, Kwan, & Bryan, 2013). These positive appraisals should lead them to feel better during exercise. Consistent with this view, research has shown that beliefs that exercise is important for health (Steptoe et al., 1997), for feeling good (Schneider & Cooper, 2011), and for having energy (Motl et al., 2002) are associated with exercise behavior or intentions. Thus, based on cognitive appraisal theories, we hypothesized that adolescents who appraised exercise as more important would experience more positive affect during and at the end of an exercise session.

Memory Bias and Affective Experience during Exercise

A second cognitive factor that may influence adolescents' feelings during exercise is biased memories for how they felt when exercising in the past. Researchers have speculated that positive or negative memories of exercise may influence future exercise adherence (Ekkekakis, Parfitt, & Petruzzello, 2011). Undergraduates who were instructed to recall a positive and motivating exercise experience reported higher levels of physical activity the following week than did those who were not instructed to recall an exercise experience, even when statistically adjusting for prior exercise behavior, attitudes, and motivation (Biondolillo & Pillemer, 2015). Memories can influence subsequent feelings as well as behaviors. Participants who were instructed to remember a successful public speaking experience had less anxiety during a subsequent public speaking task and performed the task objectively better than those who were asked to retrieve an unrelated memory (Pezdek & Salim, 2011).

Importantly, remembering is a reconstructive process, and memories of past affective experiences need not be accurate. Research based on cognitive appraisal theories of emotion has shown that episodic memory for affect fades over time. As memory fades, people draw on their appraisals of past events to help them reconstruct how they must have felt, which can lead to memory bias (e.g., Levine, 1997; see Levine, Lench, & Safer, 2009, for a review). For example, one study assessed participants' memory for their affective responses to the victory or loss of their favored candidate in an election. The more participants appraised the election as important, the more they overestimated in recalling the magnitude of their positive or negative mood (Kaplan, Levine, Lench, & Safer, 2016). Bias in memory for past feelings, in turn, influences people's future feelings, plans, and actions. For example, children with leukemia who were encouraged to remember having coped with and felt well during a lumbar puncture procedure were less distressed and coped better during a subsequent procedure (Chen, Zeltzer, Craske, & Katz, 1999). In contrast, children who overestimated in recalling the anxiety and pain they had experienced during a past lumbar puncture procedure exhibited more pain and distress during a subsequent procedure (Chen, Zeltzer, Craske, & Katz, 2000). Thus, even if memories are not veridical, remembering challenging experiences in a positive manner can improve future affective experience and influence behavior. Remembering experiences in a negative manner may negatively impact future affect and behavior.

Taken together, these findings suggest that adolescents' appraisals of the importance of exercise and bias in their memories for how they felt during past exercise should predict their affective response during subsequent exercise. Specifically, as adolescents' memory for their affective response to past exercise fades, their appraisals should influence how they remember having felt. Those who appraise exercise as more important should remember having felt better than they initially reported. In turn, positive memory bias should lead adolescents to feel better during a subsequent exercise task. Appraisals concerning the importance of exercise are abstract and may lack the immediacy of affective associations such as memories. For instance, researchers found that adults' affective associations with exercise mediated the link between their beliefs about the value of exercise and their self-reported physical activity (Kiviniemi, Voss-Humke, & Seifert, 2007). Similarly, we hypothesized that adolescents' affective memories of exercise would mediate the link between their appraisals of the importance of exercise and their affective experience during a subsequent exercise task.

Assessing Predictors of Affect during Moderate-Intensity Exercise

To test these hypotheses, the current investigation assessed predictors of adolescents' affect during a moderate-intensity exercise task. A task of moderate intensity was used because individual differences in cognitive factors such as appraisals and memories should have the greatest impact on affective responses to moderate-intensity exercise. According to the dual-mode theory of affective responses to exercise (e.g., Ekkekakis, 2009), people's feelings during exercise are influenced by both cognitive factors and interoceptive cues, but the relative

importance of these two influences shifts as a function of exercise intensity. During strenuous exercise that exceeds ventilatory or lactate thresholds, interoceptive cues (e.g., shortness of breath, increased heart rate) dominate and people typically experience negative affect. In contrast, during moderate-intensity exercise, which approaches but does not exceed ventilatory and lactate thresholds, interoceptive cues are less dominant. The greater salience of cognitive factors during moderate-intensity exercise produces more variability in people's affective responses (Ekkekakis, 2009; Stych & Parfitt, 2011).

We also selected a moderate-intensity exercise task because positive affect during moderate-intensity exercise predicts sustained physical activity. Adults who reported more positive affect during moderate exercise remained active 6 months and 12 months later (Williams et al., 2008). Increasing positive affect during the course of a session of moderate-intensity exercise was related to greater physical activity 3 months later (Kwan & Bryan, 2010). Similarly, adolescents who reported an increase in positive affect during moderate or strenuous exercise, rather than a decline or no change, engaged in more daily moderate-to-vigorous physical activity as assessed by accelerometers (Schneider et al., 2009). Thus, identifying factors that influence two aspects of adolescents' affective experience during moderate-intensity exercise—their change in positive affect and their average levels of positive affect—may be important for increasing their physical activity.

The Current Investigation

In summary, this study drew on cognitive appraisal theories of emotion to identify two cognitive factors that may predict adolescents' affective response to moderate-intensity exercise: their appraisals of the importance of exercise and bias in memory for their affective response to past exercise. We tested the following hypotheses:

(1) Adolescents who appraise exercise as more important will experience: (a) a larger increase in positive affect by the end of a moderate-intensity exercise task and (b) more average positive affect during moderate-intensity exercise.
(2) Adolescents who appraise exercise as more important will overestimate more in remembering how good they felt during a prior exercise experience.
(3) The greater their positive memory bias, (a) the more adolescents' positive affect will increase by the end of the subsequent moderate-intensity exercise task and (b) the more average positive affect they will experience during the task. Conversely, the greater their negative memory bias, the smaller the increase in positive affect and the less average positive affect they will experience.
(4) Memory bias will mediate the association between adolescents' appraisals of the importance of exercise and their affective response (change in affect, average affect) during moderate-intensity exercise. Specifically, the more important adolescents appraise exercise to be, the more they should overestimate in remembering how good they felt during a prior exercise experience. In turn, memory bias should predict positive affect during a subsequent moderate-intensity exercise task. The relationship between appraisals and positive affect will not be as strong when memory bias is included in the model.

Finding associations among cognitive appraisals, bias in memory for affect during previous exercise, and affect during subsequent exercise would be a first step toward developing cognitive interventions for increasing physical activity among adolescents. If appraisals and memory influence affective experience, then facilitating positive appraisals and memories of physical activity could enhance the effects of physical education and other exercise programs.

Method

Participants

We recruited four cohorts of participants during the fall semester of the school year in 2011–2012, 2012–2013, 2013–2014, and 2014–2015 (N = 136). Participants were beginning sixth grade at a public middle school in Southern California. We excluded data from 7 participants from analyses because the number of days between the fitness test and the assessment of remembered affect was more than 2 standard deviations greater than or less than group means. The mean age of participants was 11.03 years (SD = 0.40 years, age range = 10–12 years), and 68 participants were female. Of the participants, 47% were Latino, 19% were Non-Hispanic White, 14% were African American, 9% were Asian/Pacific Islander, and 10% were Multiracial/Other. Participants were eligible for inclusion in the larger study if they were healthy enough

to engage in regular physical activity and indicated they were not involved in a team or individual sport at the time of study recruitment. Because the larger study included electroencephalogram recordings, participants also needed to be right-handed, not be depressed, and not have a history of head trauma.

Study Design

This study was part of a larger investigation of physical activity in early adolescence that assessed whether a personalized intervention would promote physical activity (for details, see Schneider, 2014). The results showed that the intervention had no impact on participants' physical activity (Schneider, Schmalbach, & Godkin, 2017). Measures of the appraised importance of exercise and memory were not analyzed as part of the larger study.

During the fall semester of sixth grade, participants reported their cognitive appraisals concerning the importance of exercise. They also completed a test of their cardiovascular fitness and rated how they felt during this fitness test. Later that semester, participants recalled how they had felt during the fitness test. Memory for feelings was assessed after 1 week or 1 month. For the first two cohorts of participants (Group 1), the interval between the fitness test and recalling their feelings was about 1 week (M = 8.37 days, SD = 1.31 days, range = 6–12 days, N = 70). For the second two cohorts of study participants (Group 2), the interval between the fitness test and recalling their feelings was about 1 month (M = 33.65 days, SD = 6.76 days, range = 19–48 days, N = 66). The need to replace a piece of equipment midstudy led to the difference in the length of the memory retention interval across groups. However, preliminary analyses showed no statistically significant differences in the memory retention interval between the two cohorts within each group. Further, including group or the intervals between the fall fitness test, fall memory assessment, and spring exercise task as covariates in analyses did not change the statistical significance of any findings related to memory.

During the second semester of sixth grade, the same participants completed a moderate-intensity exercise task, during which they rated their affective experience. Table 1 shows the date ranges for each session and mean number of days between sessions for each group and cohort.

Measures

Appraised Importance of Exercise

To assess cognitive appraisals of the importance of exercise, we asked participants, "How important is exercise to you …" (1) "for your health?" (2) "for feeling good?" and (3) "for having energy?" Importance was rated using a scale ranging from 1 (*not at all*) to 7 (*very much*). The average of the three ratings taken in the fall semester was used as the measure of participants' appraisals of the importance of exercise (α = .82).

Cardiovascular Fitness

Each participant completed a graded exercise task on a stationary cycle that progressively increased in intensity (Schneider et al., in press). An exercise technician informed participants that they would be completing a test to "measure the maximum amount of oxygen the body can utilize." During a 4-min warm-up period, participants pedaled within a range of 60 to 80 rotations per minute (RPM). We encouraged participants to maintain that stable 60 to 80 RPM while the resistance level increased progressively by 10-watt or 15-watt increments. The test terminated when participants pedaled to volitional exhaustion. The test was followed by a 3-min cool-down period on the cycle during which participants pedaled with no resistance. Participants wore a mask and nose clips to facilitate breath-by-breath measurements, and cardiovascular fitness was

Table 1. Date ranges for the fall semester fitness test, fall memory assessment, and spring moderate-intensity exercise task and average number of days between sessions by group and cohort

	Fall semester			Spring semester	
Group and cohort	Fitness test dates	Memory assessment dates	Memory retention interval[a]	Moderate-intensity exercise task dates	Memory-to-exercise task interval[b]
Group 1					
2011–2012	9/29–11/23	10/07–11/29	8.47	4/02–5/21	151.74
2012–2013	9/24–11/07	10/02–11/15	8.29	3/25–5/14	154.71
Group 2					
2013–2014	9/23–10/21	10/23–11/21	32.30	3/24–4/14	140.23
2014–2015	9/22–10/30	10/28–11/19	35.00	3/30–5/11	155.91

[a]"Retention interval" refers to the average number of days between the fall fitness test and the fall memory assessment.
[b]The "memory-to-exercise task interval" refers to the average number of days between the fall memory assessment and the spring exercise task. Differences between groups are described in the text. Within groups, cohorts did not differ in the length of the retention interval, ts < 1.64, ps > .11. Within Group 1, cohorts did not differ in the length of the memory-to-exercise task interval, $t(68) = 0.95$, $p = .34$, but within Group 2, this interval was longer for the 2014–2015 cohort than for the 2013–2014 cohort, $t(61) = 6.29$, $p < .001$.

assessed by measuring peak oxygen uptake relative to body mass. Peak oxygen uptake relative to body mass refers to the highest rate in milliliters of oxygen consumption per kilogram of body mass per minute (VO_2peak[mL/kg/min]) measured during the task.

Affect during the Fitness Test

After completing the fitness test and stepping off the stationary cycle, participants provided a summary of their overall positive affect during the fitness test (i.e., "During the fitness test, how much did you feel good?") using a scale from 1 (*not at all*) to 7 (*very much*). This single-item scale was developed for use in this study. Single item, Likert-type scales are often used to assess affect and attitudes when ease and speed of assessment are priorities, as in the current study. Such scales have been shown in some studies to have comparable predictive validity to multi-item scales when the construct being assessed is simple and easily understood (Bergkvist & Rossiter, 2007).

Remembered Affect during the Fitness Test

We later asked participants to remember how they had felt during the fitness test. The question specified that we were asking about "the fitness test you did the first time you were in this lab when you were wearing the mask and nose clips." They rated remembered affect (i.e., "During the fitness test, how much did you feel good?") using a scale from 1 (*not at all*) to 7 (*very much*).

Affect during the Moderate-Intensity Exercise Task

The Feeling Scale (Hardy & Rejeski, 1989), a single-item scale that ranges from −5 (*very bad*) to 0 (*neutral*) to 5 (*very good*) was used to assess affective experience during the 30-min moderate-intensity exercise task. The Feeling Scale, a commonly used measure of affective responses during exercise (Stych & Parfitt, 2011), is only moderately related to ratings of perceived physical exertion during exercise (Hardy & Rejeski, 1989), and it is sensitive to different exercise intensities among adolescents (Sheppard & Parfitt, 2008). We solicited Feeling Scale ratings at baseline (on the cycle before beginning the task) and every 3 min during the task.

We created two summary measures of the affect participants experienced during the 30-min moderate-intensity exercise task: (a) change in affect and (b) average affect. We assessed change in affect because most participants feel good at the beginning of a 30-min moderate-intensity exercise task when they are not tired, but affective responses are more varied at the end of the task. Thus, change in affect from the beginning to the end of the task is likely to be sensitive to individual differences in affective responses (Schneider et al., 2009). We assessed average affect because it provides a global index of how participants felt overall during the task. To obtain change in affect, we calculated the difference between each participant's affect rating at Minute 27 (the last rating during the task) and Minute 3 (the first rating). A positive value indicates that affect was more positive at the end of the task than at the beginning, a negative value indicates that affect was more negative by the end of the task, and 0 indicates that affect was the same at the beginning and end of the task. The difference between the first and final affect ratings correlated moderately-strongly to strongly with differences obtained between ratings at Minute 3 and assessments at 12 min, 15 min, 18 min, 21 min, and 25 min (rs = .73, .79, .79, .85;ps < .001). We then conducted a regression analysis, entering baseline affect as a predictor of the difference scores and retained the residuals as the indicator of change in affect. For simplicity, we refer to these residualized change scores as "change in affect." To obtain average affect, we calculated the mean of the nine affect ratings provided during the task and regressed the mean on baseline affect. For simplicity, we refer to these residualized average affect scores as "average affect."

Procedure

Recruitment and Orientation

Families of all sixth-grade students at the school received fliers about the study, and announcements were made in physical education classes. During orientation sessions held at the school, eligible students and their parents completed assent and consent forms. All procedures were reviewed and approved by an institutional review board and by the school district's research review process.

Assessments

The timing of assessments is shown in Table 1. After the orientation session, during a regularly scheduled physical education period, participants individually visited a classroom that was set up with equipment for the fitness test. While on the stationary cycle but before beginning to exercise, participants rated their cognitive appraisals of the importance of exercise and then completed the fitness test. After a cool-down, participants reported their affect during the fitness test. During a subsequent physical education period that occurred within approximately 1 month, participants rated their remembered affect during the fitness test.

Near the end of the spring semester, participants completed a 30-min moderate-intensity exercise task

on a stationary cycle in their school's fitness lab room. The exercise technician told each participant, "Today you are going to be doing 30 min of cycling at a level we already know is within your ability." After a 2-min, low-intensity warm-up period, the resistance level (i.e., pedal tension on the bike) was set to 50% of the work rate that participants had achieved during the fitness test. We chose 50% of peak work rate as the assigned intensity to correspond to a level of intensity that has been found to be just below the ventilatory threshold—the approximate transition from predominantly aerobic to predominantly anaerobic metabolism (Reybrouck, Weymans, Stijns, Knops, & van der Hauwaert, 1985). To verify that participants were working at a level that they perceived as moderate intensity, we obtained ratings of perceived exertion (RPE; Borg, 1998) every 3 min during the task. Borg (1998) defined moderate-intensity exercise as being in the range of 12 RPE to 14 RPE. For the duration of the task, we instructed participants to pedal 60 RPM to 70 RPM. To ensure that participants would finish the moderate-intensity exercise task, the exercise technician decreased the work rate by 10 watts if a participant showed signs of fatigue—that is, if RPM dropped to less than 60 for at least 1 min or if a participant exhibited a heart rate greater than 170 beats per minute for at least 1 min. Average heart rates were well less than the ceiling of 170, a limit that was established to minimize the health risk to participants. Participants rated their affective state at baseline (on the cycle before beginning the task) and at 3-min intervals throughout the 30-min cycling task.

Data Analysis

To determine whether participants' cognitive appraisals of the importance of exercise were related to their affect during the moderate-intensity exercise task, we examined the correlations between importance appraisals and the two measures of experienced affect: change in affect and average affect. We also assessed whether bias in remembering the affect experienced during the fitness test predicted participants' affect during the moderate-intensity exercise task. Specifically, we conducted two separate regression analyses with change in affect and average affect as the dependent variables. In Step 1 of each analysis, we entered participants' global ratings of how good they felt during the fitness test. This measure was participants' overall assessment immediately after stepping off the cycle. In Step 2, we entered participants' subsequent memories of how good they felt during the fitness test. Remembered affect, adjusting for experienced affect, provided a measure of memory bias. Next, we assessed whether memory bias mediated the hypothesized relationship between the appraised importance of exercise and affect during the moderate-intensity exercise task. To do so, we first tested whether memory bias was associated with the affect variable (change in affect, average affect), a criterion for mediation. If so, we proceeded to conduct a bootstrapped mediation analysis. In this analysis, we adjusted for baseline cardiovascular fitness and group by entering them as covariates.

As part of the larger study (Schneider, 2014), participants were randomly assigned to one of two physical education program conditions between the fitness test and the moderate-intensity exercise task. Including physical education program conditions in analyses, as a main effect or as part of an interaction with other study variables, did not change the statistical significance of any of the results. Therefore, for ease of presentation, we did not include this covariate in the final analyses.

Results

Descriptive Analyses

Responses to the cognitive appraisal items showed that participants tended to view exercise as relatively important (M = 6.08, Mdn = 6.67, IQR = 5.33–7.00). Comparison of experienced and recalled affect ratings related to the fitness test revealed a moderate positive correlation between experienced and recalled affect, r = .58, p < .001; however, participants recalled more positive affect (M = 5.96, Mdn = 6.00, IQR = 5.00–7.00) than they had reported feeling immediately after the fitness test (M = 5.58, Mdn = 6, IQR = 5.00–7.00), t (135) = 3.84, p < . 001, d = 0.29. Overall, then, participants exhibited a positive bias in remembering how good they felt during the fitness test.

Participants' Feeling Scale ratings (on a scale that ranged from −5 to +5 prior to residualization) obtained during the subsequent moderate-intensity exercise task revealed that affect changed from the beginning to the end of the task. Participants scored closer to the midpoint of the scale at the end of the task (M = 2.24, Mdn = 5.00, IQR = 1.00–5.00) than at baseline (M = 3.65, Mdn = 3.00, IQR = 3.00–5.00), t (132) = −4.97, p = .001, d = 0.67. Feeling Scale ratings also indicated that on average, participants felt "good" during the task (M = 2.64, Mdn = 3.28, IQR = 1.22–4.42). Table 2 shows mean RPE and heart rates during the moderate-intensity exercise task. On average, adolescents reported exercising within the moderate-intensity range (12–14 RPE; Borg, 1998), though some participants perceived the task to be more difficult

Table 2. Means (and standard deviations) for ratings of perceived exertion (RPE) and heart rate (HR) during the moderate-intensity exercise task

Minute	3	6	9	12	15	18	21	24	27
RPE	10.78 (3.14)	12.50 (3.08)	13.33 (3.21)	13.75 (3.04)	14.32 (3.08)	14.62 (3.15)	14.98 (3.20)	15.08 (3.30)	15.12 (3.31)
HR	144.12 (14.04)	155.68 (13.65)	157.16 (12.26)	157.35 (11.55)	156.53 (11.06)	156.38 (10.89)	155.84 (11.31)	155.89 (11.00)	155.68 (11.34)

Table 3. Demographics, mean body mass index (BMI), and peak oxygen uptake (VO_2peak) during the fall and spring fitness tests by group and cohort

	Demographics			Fall fitness test		Spring fitness test	
Group and cohort	*n*	Number of female participants	Mean age	Mean BMI	Mean VO_2peak	Mean BMI	Mean VO_2peak
Group 1							
2011–2012	32	17	11.16	21.45	35.42	21.29	39.11
2012–2013	38	19	11.03	20.86	38.49	20.94	36.63
Group 2							
2013–2014	33	15	11.00	20.92	36.96	21.27	37.91
2014–2015	33	17	10.94	19.06	36.49	19.15	37.20

Note. Groups did not differ with respect to BMI or VO_2peak in the fall or in the spring, all *t*s < 1.69, *p*s > .09. Within groups, cohorts did not differ with respect to BMI or VO_2peak in the fall or in the spring, all *t*s < 1.50, *p*s > .15.

than others, suggesting they were working in the vigorous range for some of the 30 min.

Table 3 shows demographics and fall and spring fitness levels (body mass index [BMI], VO_2peak) by group and cohort. For Group 1, which included the 2011–2012 and 2012–2013 cohorts, the average interval between the fitness test and memory assessment was 1 week. For Group 2, which included the 2013–2014 and 2014–2015 cohorts, the average interval between the fitness test and memory assessment was 1 month. Therefore, we compared the two groups on all major study variables to identify any systematic differences. Groups did not differ in appraisals of the importance of exercise, age, or cardiovascular fitness in the fall or the spring (BMI, VO_2peak), all *t*s < 1.69, *p*s > .09. To determine whether memory bias differed by group, we conducted a regression analysis with group and affect ratings immediately after the fitness test as predictors of remembered affect. Group did not predict memory bias, $\beta = -0.02$, $p = .76$, $t = -0.31$.

The only differences that emerged between groups were the affective responses to the moderate-intensity exercise task. Participants in Group 2 showed a small average (residualized) positive change in affect ($M = 0.61$, $SD = 1.81$), whereas those in Group 1 manifested a small average negative change in affect ($M = -0.56$, $SD = 2.93$), $t(130) = -2.74$, $p = .007$. Group 2 also reported higher (residualized) average positive affect ($M = 0.41$, $SD = 1.57$) than Group 1 ($M = -0.37$, $SD = 2.49$), $t(130) = -2.12$, $p = .036$. Expression of positive and negative affect can vary across peer groups, even groups of the same age and from the same schools. Peer groups have been shown to play a role in adolescents' affective experience during physical activity (Fitzgerald, Fitzgerald, & Aherne, 2012). Thus, subtle differences in affective norms between Group 1 (the 2011–2012 and 2012–2013 cohorts) and Group 2 (the 2013–2014 and 2014–2015 cohorts) may have influenced participants' affective response to the moderate-intensity exercise task.

Predictors of Affect during the Moderate-Intensity Exercise Task

Appraisals of the Importance of Exercise

As hypothesized, participants who appraised exercise as more important experienced more positive affect during moderate-intensity exercise. Partial correlations, adjusting for group and VO_2peak, indicated that the more participants appraised exercise as important, the more positive change in affect they experienced by the end of the moderate-intensity task, $r(128) = .28$, $p = .002$, and the more positive affect they experienced on average during the moderate-intensity task, $r(128) = .32$, $p < .001$. Appraisals of the importance of exercise explained approximately 8% of the variance in change in affect scores and 10% of the variance in average affect scores.

Memory Bias

Next, we assessed whether participants' memory bias was related to their affective response during moderate-intensity exercise. As noted earlier, participants remembered more positive affect than they reported experiencing immediately after the fitness test. To find out if this memory bias was related to affect during the moderate-intensity exercise task, we conducted separate regression analyses with change in affect and average

affect as the dependent variables. In the first step of each analysis, we entered participants' ratings of affect immediately after the fitness test (i.e., their overall assessment immediately after stepping off the cycle). In the second step of each analysis, we entered participants' memory of how good they felt and included group (coded as 0 = Group 1, 1 = Group 2) and VO_2peak as covariates.

The results of the regression analyses are shown in Table 4. In the first step of the analysis of change in affect, experienced affect during the fitness test accounted for approximately 9% of the variance in change in affect during the moderate-intensity exercise task. In the second step, after adding remembered affect and the covariates, the model explained approximately 25% of the variance. This improvement in the fit of the model was statistically significant, $\Delta R^2 = .16$, $F(3, 127) = 8.77$, $p < .001$, and the final regression equation was statistically significant, $R = .50$, $F(4, 127) = 10.29$, $p < .001$. As noted earlier, a main effect of group was found, with participants in Group 2 reporting a greater increase in positive affect during the moderate-intensity task than Group 1, $\beta = 0.25$, $p = .001$, $t = 3.27$. Higher VO_2peak also predicted more increase in positive affect during the moderate-intensity task, $\beta = 0.20$, $p = .009$, $t = 2.64$. After accounting for the affect participants actually experienced during the fitness test, remembering more positive affect predicted a greater increase in positive affect during the moderate-intensity exercise task, $\beta = 0.30$, $p = .002$, $t = 3.19$. Remembered affect explained 6% of the variance in change in affect scores when adjusting for the other predictors. Thus, a positive memory bias was associated with more positive change in affect during subsequent exercise.

In the first step of the analysis predicting average affect during the moderate-intensity exercise task, experienced affect during the fitness test accounted for approximately 18% of the variance. After adding remembered affect and the covariates in Step 2, the model explained approximately 25% of the variance. This improvement in the fit of the model was statistically significant, $\Delta R^2 = .07$, $F(3, 127) = 3.98$, $p < .01$, and the final regression equation was statistically significant, $R = .50$, $F(4, 127) = 10.40$, $p < .001$. Again, a main effect of group was found, with participants in Group 2 reporting more average positive affect during the moderate-intensity exercise task, $\beta = 0.20$, $p = .01$, $t = 2.56$. Experienced affect, reported immediately after the fitness test, also predicted average affect during the moderate-intensity exercise task, $\beta = 0.32$, $p = .001$, $t = 3.32$. The relationship of memory bias to average affect during the moderate-intensity exercise task was in a direction consistent with our hypotheses, but this relationship was not statistically significant, $\beta = 0.18$, $p = .07$, $t = 1.85$.

Table 4. Hierarchical multiple regression analyses predicting change in affect and average affect during the moderate-intensity exercise task ($N = 132$)

	Change in affect			Average affect		
Predictor	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Step 1						
Experienced affect during fitness test	.57	.16	.39**	.68	.13	.42***
Step 2						
Experienced affect during fitness test	.22	.18	.12	.51	.15	.32*
Remembered affect	.62	.20	.30**	.31	.17	.18
Group	1.27	.39	.25**	.84	.33	.20
VO_2peak	.07	.03	.20**	.04	.02	.13*

Note. Adjusted $R^2 = .08$ at Step 1 and .22 at Step 2 for the change in affect model. Adjusted $R^2 = .17$ at Step 1 and .22 at Step 2 for the average affect model.
*$p < .05$. **$p < .01$. ***$p < .001$.

Mediation Analysis

Finally, we assessed whether memory bias explained the link between participants' cognitive appraisals of exercise and their affective response to moderate-intensity exercise. The association between appraisals of the importance of exercise and change in affect during the moderate-intensity exercise task was mediated by memory bias (mediated effect = 0.10, *SE* = .06, 95% CI [0.0199, 0.2554]; see Figure 1). This analysis controlled for VO_2peak and group. Thus, the more participants appraised exercise as important, the more they overestimated in remembering how good they had felt during the fitness test. In turn, the more positive their memory bias, the larger the increase in positive affect they experienced by the end of the moderate-intensity task. After controlling for memory bias, the association between appraised importance and change in affect during moderate-intensity exercise was no longer statistically significant.

We also planned to assess whether memory bias mediated the hypothesized association between appraised importance and average affect during the moderate-intensity exercise task. However, an association between memory bias (the putative mediator) and average affect (the outcome variable) is a criterion for mediation. This association was not statistically significant, so we did not test for mediation for average affect. Most participants felt better at the beginning of the moderate-intensity exercise task when they were not yet tired than they did at the end of the task. Thus, change in affect from the beginning to the end of the task may have been a more sensitive measure of their experience than average affect.

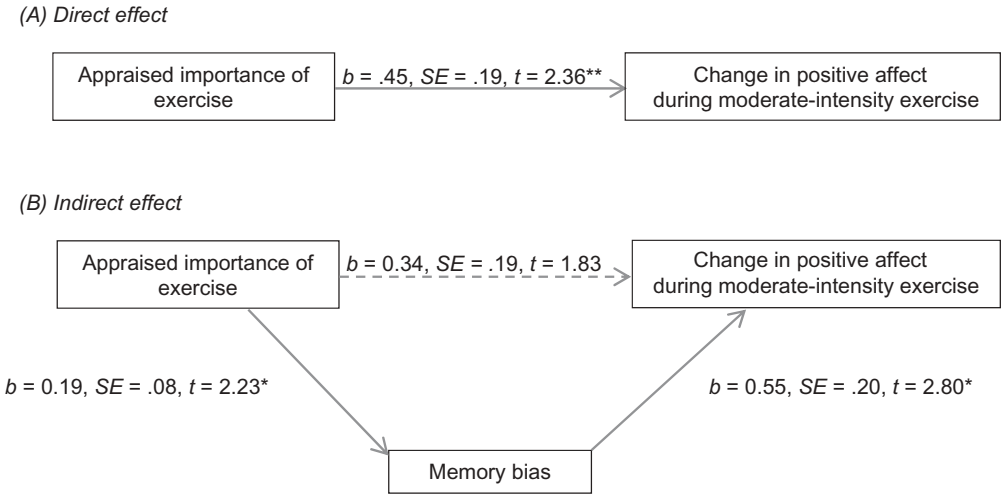

Figure 1. Memory bias refers to participants' remembered affective response to the physical fitness test, while controlling for their experienced affective response. Bias in participants' memory for their affective response to the fitness test mediated the relation between appraisals of the importance of exercise and change in affect during the moderate-intensity exercise. Unstandardized regression coefficients are presented. Analyses included cardiovascular fitness (VO_2 peak) and group as covariates. Mediated effect = 0.10, *SE* = .06, 95% CI [.0199, .2554]. The model depicted in Panel B explained approximately 26% of the variance in change in affect scores, $R = .51$, $F(5, 126) = 9.06$, $p < .001$.

*$p < .05$. **$p < .01$.

Discussion

Increasing physical activity is a public health priority, particularly in adolescence when activity levels decline (Anderssen et al., 1996). Because adolescents who experience more positive affect during exercise are more physically active (Schneider et al., 2009), this study examined predictors of affect during exercise. Specifically, we assessed sixth-grade students' change in affect between the start and end of a moderate-intensity stationary cycling task as well as their average affect during the course of the task, adjusted in both cases for baseline affect. We found that two cognitive factors predicted adolescents' affective response: their appraisals of the importance of exercise and bias in their memory for their affective response to prior exercise.

Appraisals and Memory Bias Predicted Affective Experience during Exercise

According to cognitive appraisal theories of emotion, the appraised importance of an event for attaining goals influences people's affective response to the event (e.g., Siemer et al., 2007; Sonnemans & Frijda, 1995). We hypothesized that adolescents who appraised exercise as more important would feel better by the end of an exercise session and feel more positive affect overall during exercise. Appraising exercise as important could motivate adolescents to reframe potentially aversive physiological cues in a positive manner. We found that adolescents' appraisals of the importance of exercise for the goals of being healthy, feeling good, and having energy did predict their feelings during the moderate-intensity exercise task. The more they viewed exercise as important, the more positive their feelings became from the beginning to the end of the task and the more positive affect they experienced on average during the task after statistically adjusting for cardiovascular fitness (VO_2 peak) and group. Previous research has shown that appraisals of self-efficacy are associated with positive affect during exercise (e.g., Bozoian et al., 1994). The current findings extend the demonstrated links between appraisals and positive affect during exercise to include appraisals of the importance of exercise for goals.

Adolescents' memories of how good they felt during a fitness test in the fall also predicted an increase in positive affect from the start to the end of the exercise task in the spring. Their memories were not necessarily accurate, however. Overall, adolescents remembered having felt more positive affect than they reported immediately after the fitness test. After accounting for how they actually felt during the fitness test, the more positive affect adolescents remembered (that is, the greater their positive memory bias), the more their positive affect increased during the subsequent exercise task. Qualitative data have shown that adolescents associate physiological cues such as shortness of breath or a pounding

heart with feeling poorly during moderate-to-vigorous physical activity (Stych & Parfitt, 2011). Adolescents may have drawn on their memories of how they felt during the prior cycling task to interpret such cues. Overestimating how good they had felt may have predisposed adolescents to reframe potentially aversive physiological cues as being good for their health or increasing their strength (Magnan et al., 2013), thereby contributing to an increase in positive affect from the start to the end of the task.

The finding that individual differences in cognitive appraisals and memories predicted adolescents' feelings during moderate-intensity exercise is consistent with the dual-mode theory of affective responses to exercise (Ekkekakis, 2009). According to this theory, people's affective responses to exercise are influenced both by physiological cues and cognitive factors. As exercise intensity approaches people's functional limits, physiological cues become increasingly dominant and negative affect is common. During moderate-intensity exercise, however, physiological cues do not dominate and individual differences in cognitive factors have a greater influence on people's affective responses.

Memory Bias Mediated the Link between Appraisals and Change in Positive Affect

Memories for past feelings are often biased by people's appraisals of the events that elicited those feelings (Kaplan et al., 2016; Levine, 1997). The more adolescents appraised exercise as important, the more they overestimated in remembering how good they felt during the fall fitness test. Memory bias, in turn, predicted an increase in positive affect from the beginning to the end of the moderate task. After controlling for remembered affect, the link between appraised importance and change in affect during moderate-intensity exercise was no longer statistically significant. Thus, memory bias mediated the association between adolescents' appraisals of the importance of exercise and positive change in affect during the exercise task.

In the midst of a moderately challenging exercise task, adolescents' affective memories may have been more salient to them than their abstract cognitive appraisals concerning the importance of exercise. Kiviniemi et al. (2007) also provided evidence that affective associations with exercise may be more salient than cognitive appraisals. They assessed participants' affective associations (e.g., how much joy they felt when considering physical activity) and cognitive beliefs about the value of exercise. Affective associations mediated the link between cognitive beliefs and self-reported physical activity. The researchers argued that affective associations provide a salient "shorthand" summary of the cognitively appraised value of an activity and shaper people's decisions about whether to engage in physical activity.

Researchers have also suggested that positive affective memories may promote sustained physical activity (Ekkekakis et al., 2011). Adults who were instructed to retrieve a positive memory of exercising reported more physical activity the following week compared with those who did not retrieve an exercise memory (Biondolillo & Pillemer, 2015). The current findings extend this sparse literature on memory and exercise behavior by showing that memory bias predicts change in affect during exercise. Thus, memory bias in the context of exercise may be a fruitful construct for health-related research and interventions to consider.

Future Directions and Implications

The findings of this study open exciting avenues for future research into interventions. Further exploration is warranted because adolescents' health is at stake and because the findings suggest that cognitive interventions have the potential to increase positive affect during exercise. Interventions that successfully change people's judgments concerning the benefits of engaging in physical activity are scarce despite their potential for increasing physical activity. Experiential interventions may have more promise than purely educational approaches (Rhodes, Fiala, & Conner, 2009). Thus, future interventions aimed at encouraging adolescents to appraise exercise as important for their health and well-being may benefit from being combined with experiences that promote positive associations with exercise such as exercising at a preferred intensity.

Interventions could also encourage positive memories of exercise. Children who were encouraged to remember having felt less distress during a previous painful medical procedure displayed less distress and coped better during a subsequent procedure. Moreover, benefits from this memory-based intervention lasted more than a week (Chen et al., 1999). Exercise programs could explicitly encourage adolescents to retrieve positive memories of past exercise experiences as a tool to increase positive affect and intentions to exercise (Biondolillo & Pillemer, 2015). Interventions could also promote positive memory bias by emphasizing those aspects of prior exercise that adolescents particularly enjoyed. Positive memories, in turn, may promote reframing aversive physiological cues and thereby increase positive affect during subsequent exercise. Potential downsides of memory biases should be noted, however. Remembering exercise more negatively

than actually experienced could deter people from exercising.

Future research should also explore further the specific mechanisms underlying the association between bias in memory for positive affect during past exercise and increasing positive affect during subsequent exercise. Adults are more likely to feel good during moderate-to-strenuous exercise if they perceive they have the ability to complete the exercise session, are being challenged but not overwhelmed by the task, and are benefiting from the exercise (Rose & Parfitt, 2007). Studies should explore whether adolescents who exaggerate in remembering how good they felt during strenuous exercise interpret potentially aversive physiological cues during subsequent exercise more positively and experience greater exercise self-efficacy, leading to a more positive affective experience.

Limitations of this study should be noted. This study assessed multiple cohorts of adolescents in their school during a 4-year period. Assessing adolescents' affective responses to exercise in a real-world setting is a major strength of the study, but a cohort effect was found in which some cohorts had a slightly more positive experience during the moderate-intensity exercise task than did other cohorts. Nonetheless, the appraisal and memory results were statistically significant even after adjusting for group. Although participants reported they were not engaged in organized sport at the time of recruitment, there may have been differences in the individual histories of sport participation in the sample. The study was also correlational and assessed adolescents' affective response to a school-based exercise task. In future research, it will be important to assess whether promoting positive appraisals and memories of exercise leads to increases in objective measures of adolescents' daily physical activity. Consistent with this view, adolescents' reports of more positive affect during exercise and positive change in their affective ratings during exercise have been linked to objective assessments of minutes of moderate-to-vigorous physical activity in their daily lives (e.g., Schneider et al., 2009).

Conclusion

In conclusion, most U.S. adolescents do not meet national guidelines for fitness and obesity among adolescents has reached alarming levels (Fakhouri et al., 2014). Thus, encouraging youth to be physically active is critically important (Sirard & Barr-Anderson, 2008). The results of the current study demonstrate that cognitive appraisals and memory bias play an important role in predicting adolescents' feelings during exercise. Memory bias or distortion is typically viewed as a problem, but adolescents who overestimated in remembering how good they felt during past exercise experienced a larger increase in positive affect during subsequent exercise. Thus, positive bias in adolescents' memory for their feelings during exercise may promote physical activity and be good for their health.

What does this article add?

People's appraisals of the importance of events for their goals predict their initial affective experience (Sonnemans & Frijda, 1995) as well as the feelings they later remember (Levine et al., 2016). Bias in memory for past feelings can in turn impact future feelings (for a review, see Levine et al., 2009). Ekkekakis et al. (2011) proposed that cognitive appraisals and memories for past exercise might relate to future exercise behavior. We found evidence that appraisals of exercise importance predicted adolescents' overestimation in remembering positive affect during exercise. This positive memory bias predicted an increase in positive affect by the end of a subsequent exercise task. Thus, memories of having felt good during exercise may be helpful for increasing physical activity among adolescents.

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