Published in final edited form as:

Psychol Health. 2013 April ; 28(4): 418–433. doi:10.1080/08870446.2012.733704.

Effects of current physical activity on affective response to exercise: Physical and social-cognitive mechanisms

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Abstract

Objective—Affective responses during exercise are often important determinants of exercise initiation and maintenance. Current physical activity may be one individual difference that is associated with the degree to which individuals have positive (or negative) affective experiences during exercise. The objective of this investigation was to explore physical and cognitive explanations of the relationship between current activity status (more versus less active) and affective response during a 30-minute bout of moderate-intensity exercise.

Method—Participants reported their current level of physical activity, exercise self-efficacy, and affect during a 30-minute bout of moderate-intensity exercise.

Results—More active individuals experienced higher levels of positive affect and tranquility and lower levels of negative affect and fatigue during exercise. Multivariate models for each affective state indicated separate processes through which physical activity may be associated with changes in affect during exercise.

Conclusions—These models indicate that affect experienced during physical activity is related to current activity level and these relationships can be partially explained by the physical and cognitive factors explored in this study. Recommendations for future research to elucidate whether positive affective response to physical activity improves as a function of becoming more active over time are discussed.

Keywords

affect; exercise; transdisciplinary; physiological; self-efficacy

In general, acute bouts of physical activity result in affective improvements (i.e., increased positive affect, reduced negative affect) when comparing affect from before to directly after exercise (Reed, 2005). However, research investigating affective responses experienced *during* the course of exercise shows significant individual variability in affective change (e.g., Ekkekakis, 2003). Some people do experience improvements in affect during exercise, but others experience no change or even deterioration (e.g., Parfitt, Rose, & Burgess, 2006). Contextual factors (e.g., exercise setting), aspects of the exercise stimulus (e.g., intensity), and individual differences (e.g., current activity level) may influence affective response

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during exercise (Reed & Ones, 2006). Among individuals who experience affective improvement, exercise could be self-reinforcing and thereby increase the likelihood of subsequent physical activity (Annesi, 2005). Support for this assertion comes largely from correlational and prospective studies (Bryan, Hutchison, Seals, & Allen, 2007; Kwan & Bryan, 2010a; Williams et al., 2008), allowing the possibility of a bidirectional relationship, which is the focus of the current investigation: exercising more could lead individuals to feel better during physical activity.

Affective response to physical activity can be measured in many ways, and each comes with its own strengths and weaknesses (see Ekkekakis, 2012). We use the Physical Activity Affect Scale (PAAS; Lox, Jackson, Tuholski, Wasley, & Treasure, 2000) to measure *acute exercise-induced affect*. The PAAS incorporates a multi-dimensional perspective assessing both valence and arousal. Lox and colleagues (Lox et al., 2000) originally conceptualized the PAAS to approximate the feeling states associated with the four quadrants of the circumplex model of affect (Russell, 1980): positive-high arousal (positive affect), positive low-arousal (tranquility), negative-high arousal (negative affect), and negative-low arousal (fatigue).

In general, being currently physically active has been associated with more pleasant affective experiences of exercise (e.g., improved mood, greater positive affect, increased energetic arousal). Hoffman and Hoffman (2008) compared acute mood changes before and after aerobic activity across ultramarathon runners, regular moderate exercisers, and nonexercisers ($n=16$ in each group) with the Profile of Mood States. While all groups showed some evidence of improved mood, the two exerciser groups reported increased vigor and reduced fatigue as compared to nonexercisers, and reported nearly two times the reduction in mood disturbance. Parfitt, Markland, and Holmes (1994) found that high active individuals reported more positive affect on the Feeling Scale after four minutes of intense physical activity (90% VO_2max) than low active individuals, but found little difference between the groups after four minutes at a lower intensity (60% VO_2max). Using the Activation-Deactivation Adjective Checklist, Bixby and Lauchbaum (2006) found that fit individuals (i.e. history of high physical fitness activity, $n = 15$) reported more “positive affect balance” (i.e., energetic arousal – tense arousal) during 30 minutes of aerobic activity regardless of intensity, than unfit individuals (i.e., little history of physical activity, $n = 17$).

Not all studies show an association between current activity level and affective response to physical activity. For example, Rose and Parfitt (2012) had sedentary ($n = 17$) and active ($n = 15$) women engage in two aerobic exercise sessions: one at an intensity corresponding to ventilatory threshold and one at a self-selected intensity. Using the Feeling Scale, there were no overall differences in affective response between the activity groups. Clearly, given the inconsistent findings, the differing methods used to address the question of activity level and affective response to exercise, the different ways of measuring affective response, and the small sample sizes limiting power in some studies, more research is needed to address the question of whether activity level is associated with affective response to physical activity, and if so, why.

Ekkekakis and Acevedo (2006) highlight the complexity and multifaceted nature of affective responses to exercise, suggesting that they are driven by a variety of underlying mechanisms – a perspective we also take (Bryan et al., 2007; 2011). Ekkekakis’ dual-mode hypothesis (Ekkekakis, 2003) proposes that social-cognitive and interoceptive (i.e., physiological) cues are both important predictors of affect during moderate-intensity exercise and neither alone completely determines the affective experience.

In regard to physical factors, greater physical activity has been associated with lower BMI (King et al., 1997; Seals & Chase, 1989), lower heart rate at rest and during activity (Seals & Chase, 1989; Wilmore et al., 2001), better thermoregulation during exercise (Sawka, Wenger, & Pandolf, 1996), and higher maximal oxygen uptake (ACSM, 2010; Bixby & Lochbaum, 2006). These physical factors have also been associated with affective responses to exercise: increases in body temperature have been associated with increased negative affect during exercise (Smith, Petruzzello, Kramer, & Misner, 1997), obesity (as measured with BMI) has been associated with less pleasurable experiences during an acute exercise session (Ekkekakis, Lind, & Vazou, 2010), and, although not yet assessed in an aerobic exercise setting, heart rate has been associated with experienced affect. Positive affect experienced over a 24-hour period was inversely associated with ambulatory heart rate (Steptoe, Wardle, & Marmot, 2005).

Cognitive factors are important predictors of the affective response to moderate-intensity exercise when interoceptive factors do not overwhelm the subjective experience (Ekkekakis, 2003). Exercise self-efficacy, or confidence in one's abilities to engage in physical activity, is one cognitive correlate of the affective response to exercise with extensive support (e.g., Bryan et al., 2007; Focht, Knapp, Gavin, Raedeke, & Hickner, 2007; Kwan & Bryan, 2010a). Exercisers and non-exercisers also differ in exercise self-efficacy, such that greater physical activity has been linked to higher exercise self-efficacy (e.g., Fallon, Wilcox, & Ainsworth, 2005; McAuley & Blissmer, 2000; Rose & Parfitt, 2012).

The purpose of this study was to investigate the relationship between current physical activity and affective response to physical activity, and to investigate physical and cognitive explanations of this relationship. We hypothesized that relatively more-active versus relatively less-active people will experience more affective improvement in response to exercise. We also anticipated this relationship would be mediated by differences in physical factors such as BMI, VO_2 max, body temperature, and heart rate during exercise, as well as self-efficacy (as an example of a cognitive factor). While these factors are not presumed to fully explain differences in affective response based on activity level, they are presented here as a demonstration of the physical and cognitive characteristics that may account for this relationship.

Method

Participants and Design

The current investigation utilized data from two larger exercise studies conducted at a University in the western United States. Some of the data herein have been presented elsewhere (Kwan & Bryan, 2010a; 2010b), although the analyses here and the combination of physical and affective responses are unique to this paper. The procedures were nearly identical for both studies with three exceptions. First, there was no minimum requirement for current physical activity level in the first study ($n=133$), although elite athletes were excluded. Individuals in the second study ($n=238$), were selected because they engaged in less than 90 minutes of at least voluntary moderate physical activity per week on average over the past three months. Second, individuals drawn from the second study were participating as part of a randomized controlled trial testing an exercise promotion intervention. The data reported here were collected prior to randomization and were not influenced by intervention condition. Third, participants from the first study had two separate blood draws: one prior to the exercise session and one directly after the exercise session, while individuals from the second study had an intravenous (IV) catheter inserted by a nurse to take blood samples during the exercise bout.

In both studies, individuals were recruited from the University community and surrounding area. Interested individuals were required to be able to engage in moderate-intensity physical activity, have a body mass index (BMI) between 18 and 37.5 kg/m², be nonsmokers, have no psychological disorders nor be receiving treatment, not currently on psychotropic medications or on a restricted diet, not diabetic, not have a history of cardiovascular or respiratory disease, not have had the flu or illness in the previous month, and if female, were not pregnant and had a regular menstrual cycle. All participants completed baseline questionnaires, an incremental treadmill test (VO₂max test), and a submaximal exercise test. In total, 371 individuals completed study procedures; however, one was dropped due to incomplete physical activity data, three were dropped due to inability to complete the submaximal exercise protocol, and thirteen were dropped due to excessive self reports of physical activity (minutes of physical activity two standard deviations above the mean). Thus, 354 individuals remained for analysis.

Measures

Exercise Behavior—The 7-day Physical Activity Recall (PAR; Blair et al., 1985) provides an assessment of total minutes of physical activity of varying intensities over the past week. This interviewer-administered assessment takes into account voluntary physical activity (e.g., running), as well as other forms of physical activity that may occur throughout one's day (e.g., work-related activity). The PAR has demonstrated reliability and validity (Dishman, Washburn, & Schoeller, 2001).

Exercise Self-Efficacy—On a 7-point scale (1=disagree strongly-7=agree strongly; Bryan et al., 2007), participants indicated their confidence in their abilities to: 1) do aerobic exercise for at least 90 minutes per week, 2) know how to do aerobic activity correctly, 3) do many kinds of aerobic exercise, 4) do aerobic exercise even when very busy, 5) do aerobic exercise even when feeling tired, 6) do aerobic exercise even if friends will not do it with them, and 7) do aerobic exercise even if feeling bored, $\alpha=.87$.

Affective States—The Physical Activity Affect Scale (PAAS; Lox et al., 2000), a 12-item measure modified from the Exercise-Induced Feeling Inventory (Gauvin & Rejeski, 1993), measures four exercise-induced affective states: positive affect (enthusiastic, energetic, upbeat, $\alpha=.84$), negative affect (NA; miserable, discouraged, crummy, $\alpha=.78$), tranquility (calm, relaxed, peaceful, $\alpha=.82$), and fatigue (fatigued, tired, worn-out, $\alpha=.86$). For precision, we refer to the positive affect subscale as "positive activated affect" (PAA). Participants rated each item using a 5-point scale (0=do not feel-4=feel very strongly). This measure shows adequate internal consistency and discriminant validity among the factors (Lox et al., 2000), has predictive validity for future exercise behavior and exercise motivation (Kwan & Bryan, 2010a; 2010b), and has shown measurement invariance between more and less active participants (Carpenter, Tompkins, Schmiede, Nilsson, & Bryan, 2010).

Procedure

All procedures were approved by appropriate institutional review boards. After giving informed consent, participants completed a baseline questionnaire and an incremental treadmill exercise test to assess their cardiovascular fitness by measuring *maximal oxygen uptake* (VO₂ max). Using a standard Balke protocol (ACSM, 2010) and according to previously established methods (Christou, Gentile, DeSouza, Seals, & Gates, 2005), VO₂max was assessed via online computer-assisted open-circuit spirometry using the Medgraphics Cardi02/CP system (St. Paul, MN). Weight and height were directly measured for calculation of BMI.

Approximately one week later, participants completed a 30-minute submaximal exercise session on a treadmill at 65% of their previously estimated VO_2max . At the time these studies were conducted, 65% VO_2max was consistent with the ACSM's definition of moderate-intensity physical activity (ACSM, 2000). Participants warmed up on the treadmill until they reached 65% of their estimated VO_2max (3-7 minutes) and maintained this level for 30 minutes. Participants' heart rate and expired CO_2 were intermittently assessed (using a mouthpiece) to verify they were working at an intensity equal to 65% VO_2max . After determination of 65% VO_2max , the mouthpiece was removed. *Heart rate* (HR) was monitored using a chest-transmitter HR monitor (Polar S610). *Tympanic temperature* was measured using an infrared tympanic thermometer (Welch Allyn Braun Pro 3000 ThermoScan). For each measurement during exercise, two successive readings of temperature were averaged for each time point. HR, temperature, and PAAS responses were recorded immediately prior to the bout, and at 10, 20, and 30 minutes during the bout (measured from the time at which 65% of VO_2max was achieved). The last assessment was taken immediately before ending the bout during the last minute of exercise.

Statistical Analysis

All continuously scaled variables were examined for outliers and violations of assumptions of normality. The distribution for total PAR minutes was highly skewed and was log transformed (Ln) prior to analysis. We examined the effect of current activity (Ln of minutes) on affective responses experienced during exercise using Random Coefficient Regression (RCR) in a multilevel modeling framework (Cohen, Cohen, West, & Aiken, 2003). RCR can be used to simultaneously model between and within-subject relationships for repeated measures data. In this analysis, we examined the effect of prior activity level (a fixed effect, which varies between subjects) on changes in affect during exercise (a random effect, with repeated measures of affect within subjects). Conceptually this is similar to calculating a slope for each subject for changes in affect over time during a bout of exercise, and then correlating each subject's slope with prior activity level. In these data, changes in affect over time exhibited a curvilinear trend (initial linear changes in affect, followed by a leveling off towards the end of exercise); we therefore specified both linear and quadratic trends for the within-subject slopes. The test of the fixed effect of prior activity level on a) linear and b) quadratic trends can be interpreted as the degree to which those with higher versus lower prior activity experienced a) greater linear changes in affect, and b) an attenuation of change in affect as exercise progressed. The effect sizes reported are proportional reduction in variance (PRV), comparing the residual between-subject variance in the linear and quadratic slopes in models with and without the predictor of interest (Singer & Willett, 2003). PRV provides the proportion of variance accounted for by activity level on the linear and quadratic slope of each PAAS subscale.

Using PROC MIXED in SAS Version 9.2, we first modeled changes in each affect state over time during exercise. Linear (contrast code: -3 -1 1 3) and quadratic (contrast code: 1 -1 -1 1) time were specified both as random effects and as fixed effects, allowing the assessment of patterns of change over time and whether there was variance around those effects. We then added current activity (total minutes of physical activity in the past week) and interactions between activity and linear and quadratic change. The tests of significance of the interaction terms determined whether current activity was associated with change in affect during exercise. We also addressed the more recent recommendation that exercise intensity be standardized according to whether an individual exercised above or below their own ventilatory threshold (VT; Ekkekakis, 2003; Welch, Hulley, & Beauchamp, 2010) rather than according to percent of VO_2max . Using the biometric output provided during VO_2max testing, we compared each participant's corresponding VO_2 at 65% VO_2max to his or her corresponding VO_2 at VT and coded whether participants had exercised above, at, or

below VT. We then used contrast coded variables (above/at/below VT) as control variables in the RCR analyses. Next, we calculated individual within-subject regression slopes and used these slopes as dependent variables in path models, to examine possible mediating mechanisms (VO₂max, BMI, temperature during exercise, and exercise self-efficacy) between current activity and changes in affective states during exercise. We maintained a significance level of $p < .05$ because analyses were conducted on *a priori* hypothesized relationships (Shadish, Cook, & Campbell, 2002).

Results

Participants were 354 (70.6% female, 73.4 % White/Caucasian) individuals who were 26.36 years of age on average ($SD=7.39$, range: 18-45), reported an average of 269.55 ($SD=331.30$) total minutes of physical activity in the past week, had an average VO₂max of 38.37 ($SD=9.97$), and an average BMI of 24.25 ($SD=4.23$). 33.1% of the sample met current physical activity recommendations (i.e., 150 or more minutes of at least moderate-intensity physical activity per week; ACSM, 2010). Means, standard deviations, and intercorrelations for variables of interest are shown in Supplementary Table 1. Higher levels of current activity were associated with higher VO₂max, younger age, lower BMI, male gender, higher exercise self-efficacy, and lower temperature during exercise (all $ps < .01$).

Affective Response by Current Activity Level

Figure 1 presents the trends in affective response during 30 minutes of moderate intensity physical activity by activity level for PAA (1a), tranquility (1b), NA (1c), and fatigue (1d). RCR demonstrated a significant time by activity level interaction, such that current activity was associated with both the linear [$\beta=.02$, $SE=.004$, $F(1,1057)=12.32$, $p<.001$, $PRV=.08$,] and quadratic [$\beta=-.02$, $SE=.007$, $F(1,1057)=5.06$, $p=.02$, $PRV=.07$] effects of time on PAA (Figure 1a). More active individuals exhibited significant linear ($\beta=.09$, $p<.001$) and quadratic ($\beta=-.06$, $p=.003$) changes in PAA during exercise, whereas for less active individuals there was a linear ($\beta=.03$, $p=.03$) and no quadratic ($\beta=.00$, $p=.83$) change. PAA increased during exercise, but primarily for those who were already fairly active.

Current activity was associated with the linear [$\beta=.03$, $SE=.004$, $F(1,1056)=45.16$, $p<.001$, $PRV=.21$] but not the quadratic [$\beta=.00$, $SE=.01$, $F(1,1056)=.03$, $p=.88$, $PRV=-.01$] effects of time on tranquility during exercise (Figure 1b). Tests of simple effects showed that more active individuals experienced no linear ($\beta=.00$, $p=.92$) but a positive quadratic ($\beta=.26$, $p<.001$) change, while less active participants experienced decreasing linear ($\beta=-.12$, $p<.001$) and positive quadratic ($\beta=.25$, $p<.001$) effects of time on tranquility. Initial decreases in tranquility were more pronounced among less active participants, and then tranquility increased for all participants as exercise neared completion (although more so for more active participants).

Current activity was associated with the linear [$\beta=-.01$, $SE=.002$, $F(1,1056)=11.90$, $p<.001$, $PRV=.07$] and quadratic [$\beta=.01$, $SE=.004$, $F(1,1056)=10.05$, $p=.002$, $PRV=.10$] effects of time on NA during exercise (Figure 1c). More active individuals exhibited a negative linear ($\beta=-.01$, $p=.01$) and a positive quadratic ($\beta=.02$, $p=.046$) change. Less active individuals exhibited a positive linear ($\beta=.01$, $p=.02$) and a negative quadratic ($\beta=-.03$, $p=.01$) change. More active participants tended to experience slight decreases in NA and less active participants tended to experience slight increases in NA during exercise, with both groups experiencing a tapering off of these effects as exercise neared an end.

Finally, current activity was associated with the linear [$\beta=-.02$, $SE=.004$, $F(1,1056)=17.14$, $p<.001$, $PRV=.06$] and quadratic [$\beta=.02$, $SE=.006$, $F(1,1056)=14.98$, $p<.001$, $PRV=.14$] effects of time on fatigue (Figure 1d). More active participants exhibited no linear ($\beta=.01$,

$p=.58$) but positive quadratic ($\beta=.08$, $p<.001$) changes in fatigue, whereas less active participants exhibited positive linear ($\beta=.08$, $p<.001$), and no quadratic ($\beta=-.02$, $p=.22$), changes. Fatigue increased during the bout for those who were less active, but not for those who were more active

Analyses were repeated controlling for whether participants were exercising above, at, or below VT (35.0%, 16.5%, and 35.0% of the sample, respectively). There was no significant effect of VT over and above the effects of current level of physical activity (all $ps>.10$), and controlling for VT did not substantively impact the size of the estimates or degree of significance of the interactions between physical activity and time.

Analysis of Mechanisms

We tested the effects of each proposed mediator ($VO_2\text{max}$, BMI, temperature during exercise, self-efficacy) on affect by conducting a second series of multilevel models with each physical and cognitive factor and interactions with time included as fixed effects. Higher $VO_2\text{max}$ was associated with a steeper linear increase in PAA, a decreased quadratic trend for PAA, an increased quadratic trend for NA, a steeper increase in tranquility, and an increased quadratic trend for fatigue. BMI was associated with a decreased quadratic trend in NA. Higher temperature during exercise was associated with a less steep increase in PAA, a less steep increase in tranquility, and a decreased quadratic trend in fatigue. Those with higher exercise self-efficacy had steeper increases in PAA and tranquility, and a steeper decrease in NA and fatigue, as well as an increased quadratic trend in fatigue. In general, affective responses were better for those with higher $VO_2\text{max}$, lower BMI, lower temperature during exercise, and higher exercise self-efficacy (see Table 1).

To explore the potential mediators between activity status and affective responses in a multivariate context, we estimated path models using EQS 6.1 for Windows (Bentler & Wu, 2002). Both the fit of the model and the significance of the path coefficients were examined. If paths from current activity to the mediators are significant, and paths from the mediators to the outcomes are significant, then mediation is suggested. Next, a direct path was included in the model from activity status to affective response, resulting in a one degree of freedom chi-square change (χ^2_Δ) test. A non-significant direct path, in addition to a non-significant change in model fit as assessed by the χ^2_Δ statistic, indicates mediation is complete. Finally, we estimated the size and significance of the indirect effect via the adaptation of the Sobel test (Sobel, 1982) of the two-part indirect path implemented in EQS. A significant z -score is evidence of a significant indirect (mediated) effect, and represents whether or not the indirect effect is significantly different from zero (MacKinnon, Fairchild, & Fritz, 2007).

We estimated separate models for each affective state. Current physical activity served as the sole exogenous variable, the physiological and cognitive correlates were co-equal endogenous mediators, and the linear and quadratic slopes for affect served as outcomes (see Figure 2a). The mediators were allowed to covary, as were the linear and quadratic slopes. Figure 2a shows the hypothesized model specification. We initially estimated models including age and gender, given their relationship to affective responses and the mediators, but the inclusion of these factors did not influence any of the mediational pathways, and increased the complexity of the models considerably. Thus, they were excluded from the final models.

The estimation of the model for *tranquility* showed adequate fit to the data ($\chi^2(32)=21.82$, $p<.001$; comparative fit index (CFI)=.96; standardized root mean-square residual (SRMR)=.04). Adding the direct path from activity status to linear change in tranquility resulted in a significant improvement in fit ($\chi^2_\Delta(1)=21.38$, $p<.001$), a significant direct path, and

excellent fit to the data ($\chi^2(2)=.44$, $p=.80$; CFI=1.00; SRMR=.01). Including a direct path from activity status to the quadratic slope resulted in no improvement in fit ($\chi^2_{\Delta}(1)=1.33$, ns) and a non-significant direct path, so this path was not retained. The final model with standardized parameter estimates for all significant paths appears in Figure 2b. The model accounted for 13% of variance in linear change and 2% of variance in quadratic change. Greater current activity was associated with higher VO₂max, lower BMI, lower body temperature during the bout, and greater exercise self-efficacy. These relationships are the same for each model, as this part of the model is identical in each estimation. Greater exercise self-efficacy was associated with a significantly greater increase on the linear tranquility slope. Greater VO₂max and less exercise self-efficacy were associated with a larger quadratic slope. The relationship of activity status to the linear slope of tranquility was partially mediated by self-efficacy, as there was still a significant direct effect of activity status on linear changes in tranquility when these mediators were in the model.

The fit for the *PAA* model was excellent ($\chi^2(3)=4.13$, $p=.25$; CFI=.99; SRMR=.02). Addition of a direct path from activity status to PAA did not result in any significant improvement in fit ($\chi^2_{\Delta}(1)=3.59$, ns), nor did the addition of a direct path from activity status to the quadratic slope ($\chi^2_{\Delta}(1)=.05$, ns), suggesting that mediation was complete. Consistent with this conclusion, there was a significant indirect effect of activity status on both the linear ($z=3.22$, $p<.01$) and quadratic ($z=-3.05$, $p<.01$) slopes through the mediators. There was a significant path from VO₂max to the quadratic slope of PAA ($\beta = -.15$, $p<.05$), suggesting that the relationship between activity status and the quadratic trend is primarily mediated by VO₂max. Higher VO₂max was associated with less of a quadratic trend. None of the individual paths between the mediators and the linear trend were significant, even though the overall indirect effect was significant. Given the pattern of the univariate correlations, this is likely due to a weak form of suppression (Tzelgov & Henik, 1991), such that the correlations among the mediators are larger than any of the individual correlations between the mediator and the outcome. While the *set* of mediators resulted in a significant indirect effect based on the Sobel test, the individual paths were not large enough to reach significance. Thus, the influence of each of the individual mediators by themselves on the linear slope in PAA was small. The model accounted for 4% of variance in linear change and 3% of variance in quadratic change.

The fit for the *fatigue* model was adequate ($\chi^2(3)=10.27$, $p<.05$; CFI=.98; SRMR=.03). Adding the direct path from activity status to the linear change in fatigue outcome resulted in a significant improvement in fit ($\chi^2_{\Delta}(1)=5.29$, $p<.05$), a significant direct path ($\beta=-.14$, $p<.05$), and a model with excellent fit to the data ($\chi^2(2)=4.98$, $p=.08$; CFI=.99; SRMR=.02). Including a direct path from activity status to the quadratic slope resulted in no improvement in fit ($\chi^2_{\Delta}(1)=1.69$, ns) and a non-significant direct path, so this path was not retained. There was a significant effect of exercise self-efficacy on the linear ($\beta=-.21$, $p<.01$) and quadratic ($\beta=.12$, $p<.05$) slopes, such that higher levels of exercise self-efficacy were associated with a lesser increase in fatigue and a larger quadratic slope. There was a significant effect of temperature ($\beta=-.12$, $p<.05$) on the quadratic slope. The relationship between activity status and the linear slope of fatigue was partially mediated by exercise self-efficacy, as there was still a significant direct effect when these mediators were in the model. The model accounted for 7% of variance in linear change and 6% of variance in quadratic change.

Finally, the fit for the *NA* model was adequate ($\chi^2(3)=13.48$, $p<.05$; CFI=.98; SRMR=.04). Adding the direct path from activity status to the linear change in NA resulted in a significant improvement in fit ($\chi^2_{\Delta}(1)=6.13$, $p<.05$), a significant direct path ($\beta=-.16$, $p<.05$), and a model with excellent fit to the data ($\chi^2(2)=7.35$, $p=.03$; CFI=.99; SRMR=.02). Including a direct path from activity status to the quadratic slope resulted in no improvement

in fit ($\chi^2_{\Delta}(1)=2.35$, *ns*) and a non-significant direct path, so this path was not retained. Though not statistically significant, there were trends for the effects of exercise self-efficacy ($\beta=-.11$, $p<.10$), BMI ($\beta=.12$, $p<.10$), and VO_2max ($\beta=.14$, $p<.10$) on the linear slope. None of the mediators showed a significant path to the quadratic slope, but there was a significant indirect effect of activity status on the quadratic slope ($z=2.04$, $p<.05$). The model accounted for 4% of variance in linear change and 2% of variance in quadratic change.

Discussion

This was an investigation into the potential processes involved in the relationship between current physical activity and affect experienced during exercise. We hypothesized that more physically active individuals would experience a greater degree of positive change in affect than less active individuals. Consistent with our hypothesis, greater physical activity was on average associated with a greater increase in PAA and tranquility, more of a decrease in fatigue, and slightly more of a decrease in NA during a bout of moderate-intensity exercise.

We also hypothesized that the relationship between current activity and affective response to exercise would be explained in part by physical and cognitive factors. The findings were consistent with the model proposed in Figure 2a. There were bivariate relationships between VO_2max , BMI, temperature during exercise, and exercise self-efficacy and affect during exercise. However, in a multivariate context controlling for the associations among the mediators, there were fewer unique effects. These outcomes highlight that while we replicated and supported relationships between current activity status and affect experienced during exercise, we have not completely captured the mechanisms by which these effects accrue. Indeed, we did not expect that all possible mediating factors were included in the analysis. Our findings reinforce the complexity of the relationship between current physical activity and affective responses to exercise. To the extent that support was found for some of the proposed mediators, no two of the affective states examined were influenced to the same degree via the same mechanisms. Insofar as the factors included in this study are concerned, different affective states experienced during exercise may not be universally influenced to the same degree by the same physical or cognitive factors.

The dual-mode hypothesis (Ekkekakis, 2003) suggests that the degree to which cognitive versus physiological cues influence affect is a function of the intensity of exercise. In the case of moderate intensity exercise, cognitive factors are expected to play a larger role in affective responses. The consistent relationship of exercise self-efficacy to each of the affective states examined supports this notion, and suggests that the inclusion of additional cognitions (e.g., expectancies, goals, motivation to participate, attention, autonomy, Rose & Parfitt, 2010; intrinsic motivation, Ryan & Deci, 2007) in the model may better explain the relationship. We also found some support for VO_2max , BMI, and temperature as mediators of the relationship between physical activity level and affective responses; however, other physical factors are also likely to be important. For example, we did not assess cortisol release during exercise which may be associated with PAA and NA change during exercise (Rudolph & McAuley, 1998). Our conceptual model posits that physical and cognitive factors are equal predictors of affective change, but it is likely that the complex interaction between cognitive and physical factors is integral to one's affective experience during physical activity. Cues arising from experiencing increased heart rate, increased temperature, reaching lactate threshold, and other physiological responses to physical activity may lead to differential subjective appraisals and interpretations of the physical activity situation (Rose & Parfitt, 2010; Schachter & Singer, 1962). These appraisals could magnify or attenuate the nature and intensity of an affective experience. While one person makes an appraisal that these sensations are positive ("I am getting stronger") another may

appraise the same sensations as negative (“I am too weak to do this”). Thus, the evaluation of one’s experience of physical activity is indeed a subjective experience and expanding consideration of the cognitive influences on the affective experience of exercise by measuring and incorporating these appraisals is important.

The combined effect of multiple factors (i.e., VO_2max , temperature, BMI, and exercise self-efficacy) mediated the relationship between physical activity and PAA and the relationship between physical activity and NA, but none of the individual factors were significantly uniquely associated with the outcome at conventional levels of statistical significance. Consistent with methodological work on mediation (Preacher & Hayes, 2008) and suppression (Tzelgov & Henik, 1991), this situation can result if the set of intercorrelated variables are important rather than each individual variable by itself (Preacher & Hayes, 2008). This finding again highlights the complexity of the relationship between physical activity and affect, and indicates that when searching for the mechanisms of the physical activity-affective response relationship it may be important to have a multivariate and transdisciplinary conceptualization, rather than assuming that there are one or two all-important determinants of the affective response.

There were several limitations that should be considered. First, participants were taken from two different studies; however, study group did not influence the outcomes or interpretations of the current findings. Relatedly, not all constructs were measured identically across the studies, limiting the inclusion of additional cognitive predictors. Second, our methods were based on the recommendations for moderate exercise at the time, and thus on percentage of maximal oxygen consumption (VO_2max). More recent work indicates that objectively controlling for exercise intensity in studies examining affective response may be more appropriately based on VT (Ekkekakis, 2003; Welch et al., 2010). Although we did not determine intensity based on VT, we were able to determine whether individuals exercised at, below, or above VT. Controlling for these effects did not influence our findings. Third, the warm up period for the submaximal test was not standardized; however, the range in time it took individuals to reach 65% VO_2max was minimal (3-7 minutes). This strategy allowed the duration of time each individual spent at 65% VO_2max to be standardized, ensuring that all individuals’ assessments of affect occurred consistently at 10, 20 and 30 minutes. Fourth, although we proposed the inclusion of HR in our hypothesized model, our study procedures precluded the ability to test HR in this model. The use of other testing procedures (intensity based on VT; self-selected intensity) would allow for HR to serve as a mediator in future work. Finally, and perhaps most importantly, this was a cross-sectional investigation of the relationship between activity level and affective response to physical activity; therefore, we cannot make conclusions regarding the direction of this relationship. Given the cross-sectional nature of the data, other orderings of the variables in the mediational model are possible. It may be that a more positive affective response leads to higher self-efficacy (Kwan & Bryan, 2010a), and/or greater uptake of an exercise regimen. Experimental methods are needed in order to establish the direction of effects (and possibly, the bidirectionality of effects).

Our findings are consistent with previous work showing that affective response to exercise and frequency of exercise are positively related (Bryan et al., 2007; Kwan & Bryan, 2010b; Williams et al., 2008; Williams, Dunsiger, Jennings, & Marcus, In press). However, our understanding of the causal direction of this relationship is unclear. Experimental evidence is lacking concerning whether and to what extent affective response to physical activity improves over time as a function of becoming more physically active. To address this question, more rigorous methodology is required. For instance, sedentary individuals could receive supervised standardized exercise “doses” of standardized physical activity in a longitudinal design that allowed for the assessment of change in affective response to

physical activity as a result of becoming more active. Additional questions remain as well. Is there a specific component of affect that may change more dramatically in response to physical activity or, alternatively, provide better motivation to engage in physical activity than others? Does affective response to physical activity differentially influence initiation versus maintenance of physical activity? Is it possible to enhance one's affective response to physical activity, and if so, would this increase physical activity? What is the direction of effects among interoceptive cues and social-cognitive cues in this context: Do interoceptive cues influence social-cognitive cues or vice versa?

The current investigation is a preliminary look into the mechanisms by which previous experience with exercise behavior may translate into a more positive subjective experience of exercise. Replication and extension of these findings using more robust methods and additional potential mediators is needed to better elucidate the mechanisms underlying this relationship.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The research was supported by grants awarded to Angela Bryan from the National Cancer Institute (RO1 CA109858), and the General Clinical Research Center Program of the National Center for Research Resources, National Institutes of Health (M01-RR00051) – now the Clinical and Translational Sciences Institute (UL1-RR025780). COSTRIDE, the RCT referred to in this paper, is registered on clinicaltrials.gov (NCT01091857). We would like to thank Doug Seals for developing the exercise protocols used in this research and Mark Conner for his helpful comments and suggestions on an earlier draft of this manuscript.

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Figure 1.
Trends in Affective Response During a 30-minute Bout of Moderate-Intensity Physical Activity.

Figure 2a.
Hypothesized Model.

Figure 2b.

Observed Model for Tranquility.

Note. Path coefficients are standardized estimates. Significant correlations among the mediators are included in the model but are not depicted in the figure. $\chi^2(2)=.44$, $p=.80$; CFI=1.00; SRMR=.01. ^a $p < .001$, ^b $p < .01$, ^c $p < .05$, ^d $p < .10$. The associations between current activity and the mediators are the same for each model.

Table 1
Effects of Proposed Mediators on Unstandardized Linear and Quadratic Changes in Affect During Exercise.

	Positive Activated Affect		Negative Affect		Tranquility		Fatigue	
	Linear β	Quad β	Linear β	Quad β	Linear β	Quad β	Linear β	Quad β
VO ₂ max	0.002 ^{**}	-0.004 ^{**}	-0.0003	0.002 [*]	0.004 ^{***}	0.002	-0.002 [†]	0.004 ^{**}
BMI	-0.003	0.006	0.002	-0.004 [*]	-0.004 [†]	-0.001	0.00	-0.004
Temp	-0.02 ^{**}	0.02	0.001	-0.01	-0.02 ^{***}	-0.02	0.01	-0.03 ^{***}
Self-Efficacy	0.02 ^{**}	-0.02	-0.01 [*]	0.01	0.04 ^{***}	-0.01	-0.03 ^{***}	0.04 ^{**}
Age	-0.002	0.004 [*]	0.001	-0.002	0.001	-0.008 ^{***}	0.001	-0.003
Gender	0.00	-0.06 [*]	0.03 ^{**}	0.002	0.02	0.02	0.04 [*]	0.02

* *Note.* $p < .05$,

** $p < .01$,

*** $p < .001$

[†] $p < .10$