Published in final edited form as:

J Sport Exerc Psychol. 2011 December ; 33(6): 884–902.

Unpacking the Feel Good Effect of Free-Time Physical Activity: Between- and Within-Person Associations with Pleasant-Activated Feeling States

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Abstract

Physical activity is a widely accessible and effective tool for improving well-being. This study aimed to unpack the feel good effects of free-time physical activity. Multilevel models were applied to repeated measures of daily free-time physical activity and four types of feeling states obtained from 190 undergraduate students. Physical activity was not associated with pleasant-deactivated, unpleasant-activated, or unpleasant-deactivated feelings. People who were more physically active overall had higher pleasant-activated feelings than people who were less physically active, and on days when people were more physically active than was typical for them, they reported higher levels of pleasant-activated feelings. Both the between- and within-person associations remained significant after controlling for day-of-week, sleep quality, and carryover effects of previous day free-time physical activity and feeling states. Results suggest that both increases in overall levels and acute bouts of free-time physical activity are associated with increases in feelings of pleasant-activation.

Keywords

positive-activation; mental health; exercise; daily diary

The feel good effects of physical activity have been shown in response to prescribed exercise in the laboratory (Reed & Buck, 2009; Reed & Ones, 2006), as well as with physical activity in field-based, naturalistic contexts (Kanning & Schlicht, 2010; Reed & Buck, 2009; Schwerdtfeger, Eberhardt, & Chmitorz, 2008). The present study used a daily diary design to extend previous research on the feel-good effects of physical activity by (a) establishing relations between daily free-time physical activity and different types of feeling states, (b) testing whether these associations manifest at both between- and within-persons levels, and (c) determining if the noted associations endure after controlling for the potentially confounding factors of day-of-week, sleep quality, and the carryover of previous-day physical activity and feeling states.

The Feel-Good Effects of Physical Activity

Recent literature reviews revealed that acute bouts of exercise and exercise intervention programs lasting 4–32 weeks increased feelings such as energy, vigor, pleasant mood,

pleasant affect, and joy (Reed & Buck, 2009; Reed & Ones, 2006). Though these reviews provide strong evidence to support the claim that prescribed physical activity increases pleasant-activated feelings, there is only a small amount of evidence that tested this claim using physical activity within the context of daily life. Studies on the feel good effects of daily life physical activity have not systematically identified the specific type of pleasant feelings that physical activity elicited (Giacobbi, Hausenblas, & Frye, 2005; Hausenblas, Gauvin, Downs, & Duley, 2008; Mata et al., 2011; Schwerdtfeger et al., 2008; Steptoe, Kimbell, & Basford, 1998; Watson, 1988).

Ekkekakis and Petruzzello (2002) proposed that both valence (pleasant-unpleasant) and activation (activated-deactivated) should be considered to fully characterize the feel-good response to physical activity. Since this proposal, studies assessing the link between physical activity and both affective valence and activation have appeared (e.g., Ekkekakis, 2003; Ekkekakis, Hall, & Petruzzello, 2005; Kilpatrick, Kraemer, Bartholomew, Acevedo, & Jarreau, 2007). To extend this previous research, this study investigated the link between physical activity and feeling states characterized by both valence and activation. Our intent is to help clarify if physical activity impacts the feeling states that can result in the maintenance or change in core affect (Russell, 2003). *Pleasant-activated* feelings are exemplified by excitement and enthusiasm, *unpleasant-activated* feelings include anxiety and anger, *pleasant-deactivated* feelings are exemplified by satisfaction and relaxation, and *unpleasant-deactivated* feelings include depression and sadness.

One recent study found that both pleasant-activated and pleasant-deactivated feelings (i.e., pleasantness, energy, and calmness) were higher following events categorized as involving physical activity than following events that were categorized as not involving physical activity (Kanning & Schlicht, 2010). Another study showed that feelings of pleasant-activation were highest after episodes of physical activity in depressed and normal samples, but did not test pleasant-deactivated feelings (Mata et al. 2011). These studies provide insight into how people feel immediately after physical activity, but do not determine if these feeling states are sustained long enough or are powerful enough to be incorporated into reflections of daily feeling states that also include reflections on all other events of the day.

Other research showed that people have more pleasant feelings on days when they are physically active than on days when they are not physically active, but did not differentiate between high and low activation of the daily pleasant feeling states (e.g., Giacobbi et al., 2005; Hausenblas et al., 2008; Schwerdtfeger et al., 2008; Steptoe et al., 1998; Watson, 1988). Further research is necessary to clarify whether the feel-good effect of physical activity seen on a daily level involves pleasant-activated feelings, pleasant-deactivated feelings, or both.

It is important to establish the activation of the pleasant responses to physical activity because activation is a major distinction between two of the most distressing feeling states. Depression is defined by negative mood and low arousal; whereas anxiety is defined by negative mood and high arousal (Clark & Watson, 1991). To most effectively impact depressive feelings, increases in both pleasantness and activation should be targeted. To impact anxious feelings, on the other hand, aims should be directed at increasing

pleasantness while decreasing activation. Specifying which type of feeling states are influenced by daily free-time physical activity will help define how physical activity can best serve as a tool for managing feelings of depression and anxiety.

The relative magnitude of physical activity effects on symptoms of anxiety and depression suggests that physical activity enhances pleasant-activated feelings specifically. The effect of physical activity on depression is about twice as large as the effect of physical activity on anxiety (Rethorst, Wipfli, & Landers, 2009; Wipfli, Rethorst, & Landers, 2008). This difference in effect sizes may indicate that physical activity enhances feeling states that reduce anxiety by altering valence alone whereas it reduces depression by altering feeling states that enhance both affective valence and activation. This hypothesis is supported by one of the leading theories for explaining the feel-good effect of physical activity.

The *monoamine enhancement theory* proposes physical activity enhances synaptic transmission of monoamines in the brain, including norepinephrine, dopamine, and serotonin (Acevedo & Ekkekakis, 2006; Chaouloff, 1989; Ransford, 1982). These monoamines result in feelings of elevated mood and activation – a pattern bearing strong similarity to pleasant-activated feelings. In light of this neurobiological mechanism and the strong evidence supporting the effect of prescribed physical activity on pleasant-activated feelings in laboratory studies, we expected that free-time physical activity in daily life would be associated with increased pleasant-activated feeling states, but not with pleasant-deactivated, unpleasant-activated or unpleasant-deactivated feeling states.

Between- and Within-Person Associations of Free-Time Physical Activity and Feeling States

Previous research has shown that individual differences in the effect of physical activity on feeling states can average out, resulting in a misleading null effect when considered at a mean level (Van Landuyt, Ekkekakis, Hall, & Petruzzello, 2000). Thus, it is important to consider whether the relation between daily free-time physical activity and feeling states is driven only by between-person differences or whether it may also be present at a within-person level. It is possible to separate these effects (Kenny, Kashy, & Bolger, 1998) and ask two conceptually distinct questions: (1) Do people who engage in more overall free-time physical activity have different feeling states than their peers with less free-time physical activity (a between-person effect)?; and (2) Do individuals have different feeling states on days when they engage in more free-time physical activity than on days when they engage in less free-time physical activity (a within-person effect)? The answers have direct implications for whether practitioners should promote lifestyle change (between-person differences) and/or acute bouts of physical activity (within-person differences) to relieve distressing feeling states.

Both the between-person hypothesis (e.g., Stephens, 1988) and the within-person hypothesis (Giacobbi et al., 2005; Hausenblas et al., 2008; Kanning & Schlicht, 2010; Watson, 1988) have preliminary support in the literature; however, rarely have these hypotheses been tested simultaneously. Based on the available evidence, we expect that both between- and within-

person associations between free-time physical activity and pleasant-activated feeling states will be evident when examined simultaneously.

Previous research has also shown that there may be differences in the biological markers connected to the feel-good response to physical activity depending on fitness of the individual (Petruzzello, Hall, & Ekkekakis, 2001). One might assume that people who engage in more overall physical activity will be more fit than people who engage in less physical activity. Accordingly, overall free-time physical activity could conceivably moderate relations between daily free-time physical activity and feeling states. This study will investigate this possibility.

Alternative Explanations

There is little research testing the impact of potentially confounding factors on the association between free-time physical activity and pleasant-activated feeling states. It is possible that additional factors such as day of the week, quality of sleep, or daily carry-over of physical activity or feeling states are the cause of the significant relations between free-time physical activity and pleasant-activated feeling states. For example, there is a tendency for people to engage in physical activity and experience changes in mood in accordance with the typical weekday weekend cycle (Ram et al., 2005; Sequeira, Rickenbach, Wietlisbach, Tullen, & Schutz, 1995; Tudor-Locke et al., 2005). It may be that significant daily relations between physical activity and pleasant-activated feeling states are artifacts of on-going cyclic processes associated with the social calendar. As well, there is evidence that physical activity leads to enhanced sleep quality (King, Oman, Brassington, Bliwise, & Haskell, 1997; Singh, Clements, & Fiatarone, 1997), which in turn leads to more pleasant feelings (Pilcher, Ginter, & Sadowsky, 1997; Steptoe, O'Donnell, Marmot, & Wardle, 2008). This chain of processes may account for daily relations between free-time physical activity and pleasant-activated feeling states. Additionally, the association between daily free-time physical activity and pleasant-activated feeling states may result from carry-over effects of free-time physical activity and/or pleasant-activated feeling states from the previous day. By testing the relation between daily free-time physical activity and pleasant-activated feeling states after controlling for each of these potentially extraneous factors, this study seeks to rule out these four alternative explanations for the relation between daily free-time physical activity and pleasant-activated feeling states.

Purpose of this Study

Research supports the theory that free-time physical activity results in a feel-good effect but can be refined by (1) providing more precision about which specific feeling states respond to free-time physical activity, (2) differentiating between- and within-person sources of variation, and (3) ruling out plausible alternative hypotheses involving third variables. This study was designed to address some of the limitations in previous work and thereby clarify relations between daily free-time physical activity and daily feeling states.

In line with the aims of the study, we formulated four specific hypotheses. First, we hypothesized that daily free-time physical activity would be associated with daily pleasant-activated feeling states but not pleasant-deactivated, unpleasant-activated, or unpleasant-

deactivated feelings. Second, we expected that people who were more physically active in their free-time overall would have more pleasant-activated feeling states than others who were less active in their free-time overall. Third, we hypothesized that on days when people were more physically active in their free-time than was typical for them, they would have more pleasant-activated feeling states. Finally, we expected that both the between- and within-person associations between free-time physical activity and pleasant-activated feeling states would remain significant, after controlling for potential confounds of day of the week, sleep quality, or the carryover of previous day free-time physical activity or pleasant-activated feeling states.

Method

We applied multilevel models to daily data from the Pennsylvania State University Achievement Motivation and Interpersonal Behavior (AMIB) Study. Comprehensive information about the larger, multiple time-scale study is reported in Ram, Conroy, Pincus, Hyde, and Molloy (2011). Details relevant to the present analysis are given below.

Participants & Procedures

Participants were 190 university students (66% women, $M_{\text{age}} = 19.3$ years, $SD_{\text{age}} = 2.8$ years) enrolled in introductory psychology courses who completed the study protocol in exchange for partial course credit. These primarily first (61%) and second year (25%) students were mostly Caucasian (83%) with some representation of American Indian or Alaska Native (6%), Hispanic or Latino (5%), African American (3%), and Mixed or Other (3%) ethnicities.

In brief, students began their participation by attending a 1.5 hour introductory session in the evening at which they provided informed consent, were trained in the study procedures, and completed questionnaires. They were given eight small booklets that included questions about daily lived experiences (e.g., sleep quantity and quality, free-time physical activity) and mental states (e.g., perceived stress, self-esteem, feeling states). The first daily diary booklet was completed during the evening training session and participants were instructed to complete additional diaries shortly before they went to bed each evening for the next seven days. Completed diaries were returned to the laboratory each day through the campus mail system.

Across the entire study period, diary booklets were returned in a timely and comprehensive manner. Overall, data from 1,458 of the 1,520 possible person-days were obtained (a 96% response rate), with 87% of participants ($n = 165$) completing all 8 days worth of reports ($\text{Median}_{\text{of days}} = 8$, $\text{Mean}_{\text{of days}} = 7.67$, $SD_{\text{of days}} = 1.14$). All study protocols were approved by the local institutional review board and all participants gave informed consent and permission for their data to be used for research purposes.

Measures

Daily Free-Time Physical Activity—Individuals' daily free-time physical activity was measured using an adapted version of the Leisure Score Index of the Godin Leisure Time Exercise Questionnaire (LTEQ; Godin, Jobin, & Bouillon, 1986; Godin & Shepard, 1985), a

validated measure of adult weekly free-time physical activity (Jacobs, Ainsworth, Hartman, & Leon, 1993). The measure was adapted to assess free-time physical activity on a daily time scale and to be more sensitive to shorter bouts of physical activity. Specifically, as part of their end-of-day reports, participants were asked to indicate how many times they engaged in (1) strenuous (e.g., running, basketball), (2) moderate (e.g., fast walking, volleyball), and (3) mild exercise (e.g., easy walking, yoga) for at least 10 minutes throughout their free-time during the day. The 10 minutes or longer criteria used in the measure matched national guidelines for recommendations about physical activity (Physical Activity Guidelines Advisory Committee, 2008). Following the LTEQ scoring procedure, a summary score reflecting amount of energy expenditure (metabolic equivalents) was calculated as the weighted sum of the number of bouts reported for each of the three items ($3 \times \text{mild} + 5 \times \text{moderate} + 9 \times \text{strenuous}$).

Daily Feeling States—Individuals' daily feeling states were measured using 20 items separated into four groups based on the quadrants of core affect space obtained when crossing valence and activation dimensions (Kuppens, Van Mechelen, Nezlek, Dossche, & Timmermans, 2007). Specifically, participants were asked, "Looking back on everything that happened to you today and considering the day as a whole, please circle a response to each question below. Today I felt ..." Five items were used to assess each type of feeling state. Pleasant-activated states were assessed using the terms enthusiastic, happy, alert, proud, and excited (Cronbach's $\alpha = .81$, range across days = .75 to .85). Pleasant-deactivated states were assessed using the terms calm, peaceful, satisfied, relaxed, and content ($\alpha = .87$, range = .84 to .89). Unpleasant-activated states were assessed using the terms nervous, embarrassed, upset, stress, and tense ($\alpha = .81$, range = .79 to .81). Unpleasant-deactivated states were assessed using the terms sluggish, sad, bored, depressed, and disappointed ($\alpha = .74$, range = .67 to .70). Within each set of items, participants' responses on the 1 (*did not feel this way at all*) to 7 (*felt this way strongly*) Likert-type response scales were averaged to obtain the four general feeling state scores.

Most of these feeling states have been shown to fit within the noted core affective quadrants when their (between-person) dimensional structure has been investigated (Feldman Barrett & Russell, 1998; Feldman, 1995; Russell, 1980). The feeling states that have not been empirically compared to the affective circumplex (enthusiastic, proud, peaceful, and embarrassed) have valence and activation characteristics that are conceptually similar to their grouped feeling states and have been shown to have high covariation with other words of the same grouping (Fisher, 1998; Huelsman, Nemanick, & Munz, 1998; Lewis, 2008).

Covariates—To control for some possible alternative explanations, our follow-up analyses included additional variables. Each day, participants reported on their *daily sleep quality* (Did you sleep well last night?) on a 0 (*not at all*) to 5 (*extremely*) Likert-type scale. *Day-of-the-week* effects were incorporated through inclusion of six binary variables indicating the day on which each repeated measure was obtained (Sunday through Friday, with Saturday serving as the reference category).

Data Analyses

Taking advantage of the nested nature of the data (days nested within persons), we used two-level models to test (a) between- and within-person associations between free-time physical activity and four types of feeling states and (b) the impact of potential confounds on the between- and within-person association between free-time physical activity and feeling states. Models were estimated using SAS 9.2 PROC MIXED (SAS Institute Inc., 2008). For consistency across the analyses with and without prior day reports, data from the initial session of the study were not included in the analyses. Additionally, a small number of incomplete reports ($n_{obs} = 50$, 4%) were also removed. The final analysis sample consisted of 1,218 days of data nested within 186 people. The pattern of results did not differ with and without inclusion of the initial day's data or incomplete cases.

Data Preparation—Following standard procedures for separating between-person and within-person associations, we person-centered our predictor variables (see e.g., Schwartz & Stone, 1998). For example, we calculated each person's level of overall free physical activity (*OverallPhys_i*) as the mean of his/her repeated measures, and each person's daily level of free-time physical activity as the daily deviation around his/her overall level (*DailyPhys_{di}*). These time-invariant (mean-level) and time-varying (daily deviations) variables were then used within the multilevel modeling framework to test our hypotheses, and rule out some alternative explanations.

Between- and Within-Person Associations of Free-Time Physical Activity and Feeling States—Each of the four types of feeling states was regressed onto free-time physical activity to assess the extent of between-person and within-person associations. The model was specified as

$$\text{Level-1: Feeling States}_{di} = \beta_{0i} + \beta_{1i}(\text{DailyPhys}_{di}) + e_{di} \quad (1a)$$

$$\text{Level-2: } \beta_{0i} = \gamma_{00} + \gamma_{01}(\text{OverallPhys}_i) + u_{0i} \quad (1b)$$

$$\beta_{1i} = \gamma_{10} + \gamma_{11}(\text{OverallPhys}_i) + u_{1i} \quad (1c)$$

where Feeling States_{di} is the feeling states score (pleasant-activated, pleasant-deactivated, unpleasant-activated, or unpleasant-deactivated) on day *d* for individual *i*, β_{0i} is a person-specific intercept, β_{1i} is a person-specific association between daily free-time physical activity and feeling states, and e_{di} are time-specific residuals. The person-specific intercepts and slopes are then modeled at Level-2, where γ_{00} represents the expected level of feeling states for a person who did not engage in free-time physical activity, γ_{01} represents the between-person association between free-time physical activity and feeling states, γ_{10} represents the average within-person association between daily free-time physical activity and feeling states, γ_{11} reflects the extent to which overall free-time physical activity moderates the within-person association between daily free-time physical activity and feeling states, and u_0 and u_1 are residual variances unexplained by between-person differences. As a measure of effect size, pseudo- R^2 were calculated as the difference in the

unexplained variance in the restricted model and the unexplained variance of the unrestricted model (with no predictors) divided by the unexplained variance in an unrestricted model (Kreft & De Leeuw, 1998; Raudenbush & Bryk, 2002; Snijders & Bosker, 1999).

After establishing if and how free-time physical activity was related to feeling states, we expanded the relevant models to rule out some possible alternative explanations of those relations. Specifically, we controlled for day-of-week, sleep quality, and carry-over of feeling states and free-time physical activity from the previous day. At the within-person level (Level 1), we introduced six day-of-week dummy variables (Sunday, Monday, Tuesday, Wednesday, Thursday, Friday), quality of previous night's sleep, feeling states of the previous day, and free-time physical activity of the previous day. At the between-person level (Level 2), we introduced individuals' overall sleep quality (within-person mean).

Results

Descriptive information is presented in Table 1. As expected, this sample of undergraduate students' daily lives were generally characterized by relatively high levels of pleasant feeling states (e.g., pleasant-activated feeling states $M = 3.93$ on a 1 to 5 scale), relatively low levels of unpleasant feeling states (e.g., unpleasant-deactivated feeling states $M = 2.30$), and average free-time physical activity levels that were equivalent to participation in more than two moderate bouts of activity per day, exceeding the national guideline recommendations ($M = 12.47$). The daily diary design captured substantial variability in free-time physical activity, sleep quality, and all four types of feeling states, existing both at the between- and the within-person levels. Intraclass correlation [ICC] estimates reflect the proportion of between-person variance and ranged from .34 to .55 for these variables.

Correlations are presented for both overall between-person variables (e.g., OverallPhys) and within-person variables (e.g., DailyPhys). Free-time physical activity had similar relations with pleasant-activated feeling states at between- ($r = .13$) and within-person levels ($r = .09$), but other types of feeling states showed more divergence in the magnitude and direction of relations with free-time physical activity across these two levels of analysis. The magnitude of the relation between free time physical activity and pleasant-deactivated feeling states was larger at the between-person level ($r = .09$) than at the within-person level ($r = .01$). Also, free-time physical activity was seemingly unrelated to unpleasant-deactivated feeling states at the between-person level ($r = .03$), but showed a small negative relation at the within-person level ($r = -.11$). In sum, both the between-person and within-person "zero-order" relations suggested further examination was warranted.

Free-Time Physical Activity and Feeling States

To test the extent of the within- and between-person associations between free-time physical activity and the four aspects of feeling states more precisely, we ran four multilevel models. Results are given in Table 2. Interpreting the results from the first model, we found that higher levels of free-time physical activity were associated with higher levels of pleasant-activated feeling states, both between-persons ($\gamma_{01} = 0.02, p = .0001$) and within-persons ($\gamma_{10} = 0.03, p < .01$). That is, people who engaged in more free-time physical activity overall

had higher overall levels of pleasant-activated feeling states, and on days when people were more physically active in their free-time than was typical for them, they reported higher levels of pleasant-activated feeling states. Of note, the within-person association was not moderated by differences in overall levels of free-time physical activity ($\gamma_{11} = -0.001$, $p = .15$), nor were there significant random effects in the association between daily free-time physical activity and pleasant-activated feeling states ($\sigma^2_{u1} = 0.0002$, $p = .22$), an indication that the within-person association was pervasive (i.e., held for all persons). Based on pseudo R^2 , free-time physical activity accounted for 4% of variance in pleasant-activated feeling states.

As seen in Table 2, significant associations were not detected in the second, third, and fourth models. In sum, there was no evidence that between-person differences or day-to-day changes in free-time physical activity were associated with individuals' pleasant-deactivated, unpleasant-activated, or unpleasant-deactivated feeling states ($p > .05$ for all γ of interest). Based on pseudo R^2 , little variance in these other feeling states (pleasant-deactivated = 2%, unpleasant-activated = 2%, unpleasant-deactivated = 1%) was accounted for by free-time physical activity.

Ruling Out Alternative Explanations

Our four initial models suggested that associations between free-time physical activity and feeling states were restricted to pleasant-activated feelings. Having isolated the feel-good effect, we sought to eliminate a number of alternative explanations by incorporating additional explanatory variables at both the between- and within-person levels. Results from the expanded model are given in Table 3. We found that there were (a) significant day-of-week effects, such that pleasant-activated feeling states were lower Sunday through Thursday (γ s between -0.46 and -0.25 , $ps < .05$) than on Saturday (the reference day); (b) significant within-person effects of sleep quality, such that pleasant-activated feelings was higher on days that followed better than usual quality of sleep ($\gamma_{80} = 0.17$, $p = .0001$); and (c) no evidence of carry-over effects for previous-day pleasant-activated feeling states ($\gamma_{90} = 0.01$, $p = .86$) or previous-day free-time physical activity ($\gamma_{100} = -0.0004$, $p = .92$) on pleasant-activated feeling states. At the between-person level we found that (d) higher overall sleep quality was associated with higher levels of pleasant-activated feeling states ($\gamma_{02} = 0.44$, $p = .0001$). Most importantly, both the within-person ($\gamma_{10} = 0.02$, $p = .02$) and between-person ($\gamma_{01} = 0.02$, $p = .005$) associations between pleasant-activated feeling states and free-time physical activity remained significant. As before, there was no evidence that the within-person association was moderated by differences in overall levels of free-time physical activity ($\gamma_{11} = -0.0004$, $p = .46$). There were significant random effects in the extent of the association between free-time physical activity and pleasant-activated feeling states after controlling for all the other constraints of the model ($\sigma^2_{u1} = 0.04$, $p = .02$). In sum, day-of-week, sleep quality, and carry-over of feeling states and free-time physical activity did not account for the within-person or between-person associations between free-time physical activity and pleasant-activated feeling states.

Discussion

This study unpacked relations between physical activity and feeling states by investigating both between- and within-person sources of association between free-time physical activity and four types of feeling states. Significant amounts of within-person variation were evident in both daily feeling states and free-time physical activity. Between- and within-person variation in free-time physical activity was associated with daily pleasant-activated feeling states. Neither between- nor within-person associations were found between free-time physical activity and pleasant-deactivated, unpleasant-deactivated, or unpleasant-deactivated feeling states. This study also tested the association between free-time physical activity and pleasant-activated feeling states controlling for potentially confounding factors, with the evidence suggesting that daily relations between free-time physical activity and pleasant-activated feelings were not a result of any of the alternative factors examined within this study.

Between- and Within-Person Variability in Free-Time Physical Activity and Feeling States

Daily free-time physical activity and daily feeling states were shown to have both between- and within-person components. The amount of between-person variability found in daily feeling states in this study was similar to that found in previous research of adults (ICCs range .28 to .43; Röcke, Li, & Smith, 2009). Roughly half of the free-time physical activity variance existed at the between-person level ($ICC = .55$). Previous research, considering both subjective and objective measurements, has also found considerable amounts of within-person variation in physical activity (Levin, Jacobs, Ainsworth, Richardson, & Leon, 1999). Considering the volume of research on the link between feeling states and physical activity that has focused exclusively on between-person associations (i.e., chronic effects), these results suggest that explanations of the within-person variation (i.e., acute effects) are as important as the explanations of between-person variation. As a first step, our findings suggest that *both* chronic and acute physical activity are related to pleasant-activated feeling states.

Free-Time Physical Activity and Pleasant-Activated Feeling States

Results supported our hypothesis that physical activity would be associated with pleasant-activated, but not pleasant-deactivated, unpleasant-deactivated, or unpleasant-deactivated feeling states. This finding extends previous research in three important ways. First, previous research showed daily physical activity was related to feeling pleasant, but did not differentiate the effects on pleasant-activated and pleasant-deactivated feeling states (e.g., Giacobbi et al., 2005; Hausenblas et al., 2008; Mata et al., 2011; Schwerdtfeger et al., 2008; Steptoe et al., 1998; Watson, 1988). This study pinpointed the feel-good effect of daily free-time physical activity to pleasant-activated feelings. Previous studies have linked episodes of physical activity to the pleasant-deactivated feeling state of calmness (Kanning & Schlicht, 2010), but this association did not generalize to daily free-time physical activity in the current study which sampled a broader range of pleasant-deactivated feeling states.

Second, this study extended previous research by showing that physical activity was associated with pleasant-activated feelings in real-life settings. Our findings suggest that

previous conclusions about the feel-good impact of acute physical activity and physical activity interventions (Reed & Buck, 2009; Reed & Ones, 2006) may generalize to ecologically valid, free-time physical activity at the daily level. Third, this study extends previous research on the immediate feel-good responses to self-initiated physical activity (Kanning & Schlicht, 2010; Mata et al., 2011). Our findings suggest that physical activity has an impact on feeling states that is long enough to manifest at a daily time-scale and is powerful enough to be incorporated within feeling states reflective of all daily events.

Our findings, obtained through study of relatively healthy and happy students, are consistent with reviews on the effects of physical activity on mental health and the monoamine theory of the feel-good influence of physical activity (Acevedo & Ekkekakis, 2006; Chaouloff, 1989; Ransford, 1982; Rethorst et al., 2009; Wipfli et al., 2008) and research showing that self-initiated physical activity leads to immediate increases in pleasant-activated feelings in normal and depressed populations (Mata et al., 2011). That daily free-time physical activity was associated with pleasant-activated feeling states, but not with pleasant-deactivated feeling states suggests some differentiation with respect to activated versus deactivated feeling states. As such, physical activity may hold more promise as an intervention for depression than as an intervention for anxiety. Future research needs to further evaluate the specific physiological mechanism(s) of the feel-good influences of physical activity as well as the role that activation plays in explaining physical activity intervention effects on mental health.

Between- and Within-Person Associations

As expected, free-time physical activity was associated with pleasant-activated feeling states at both the between- and within-person levels. These findings extend previous research that has demonstrated either between- or within-person associations between free-time physical activity and feeling states (e.g., Giacobbi et al., 2005; Hausenblas et al., 2008; Kanning & Schlicht, 2010; Stephens, 1988; Watson, 1988) by separating and simultaneously testing the association among between- and within-person changes in free-time physical activity and feeling states. These results provide evidence that people who are more physically active in their free-time than others have more overall pleasant-activated feeling states, and, on days when people are more physically active in their free-time than typical, they experience more pleasant-activated feeling states. The practical implication is that both lifestyle changes in physical activity and increases in acute bouts of daily physical activity may contribute to individuals' well-being.

Overall free-time physical activity was not found to moderate the relation between daily free-time physical activity and feeling states, suggesting the feel-good effect of physical activity is not specific to more or less physically active individuals and the feel-good benefits of physical activity can be promoted to a broad audience of people with varying levels of physical activity and physical fitness.

Ruling Out Alternative Explanations

The third major finding from this study was that relations between daily free-time physical activity and pleasant-activated feeling states remained significant even after controlling for

the day-of-week, sleep quality, and the carryover of free-time physical activity and feeling states from the previous day. We ruled out the competing hypotheses that the relation between free-time physical activity and pleasant-activated feeling states was a result of these extraneous factors. To further strengthen the direct relation between free-time physical activity and pleasant-activated feeling states, other potential confounds that have been shown to be related to both physical activity and feeling states should be considered including, but not limited to, perceived stress (Aldana, Sutton, Jacobson, & Quirk, 1996; van Eck, Nicolson, & Berkhof, 1998) and self beliefs (McAuley et al., 2005; Wood, Heimpel, & Michela, 2003).

Limitations and Outlook

Although these results advance our understanding of relations between physical activity and feeling states, a few limitations must be recognized. First, the sample primarily consisted of young, high-functioning, white adults. Future research with more diverse samples is necessary before generalizing these results to broader populations. Second, free-time physical activity was measured via subjective, retrospective daily self-reports. Incorporating objective measures of physical activity within future studies will control for either over- or underestimations of self-reported free-time physical activity. Additionally, future research incorporating the assessment of physical activity in occupational and other contexts is necessary before generalizing the effects in this study beyond free-time physical activity.

Third, as with all daily diary studies, our daily end-of day assessments of feeling states were vulnerable to recall biases and feeling states at the time of the assessment (Ebner-Priemer & Trull, 2009; Hufford, 2007; Shiffman, Stone, & Hufford, 2008). Future research can extend this study by assessing momentary feeling states to more precisely investigate the longevity of the effect without the threat of recall bias. Future research sampling physical activity and feeling states intensively within days (e.g., on an hourly time scale) will extend our knowledge across multiple time-scales (Ram & Gerstorf, 2009). More frequent sampling will allow for testing for within-day temporal sequences and potentially help clarify the causal direction of associations of physical activity and feeling states.

As investigations shift to faster time scales, it may be helpful to shift from the 20-item measure used here to less-demanding measures of specific feeling states. For example, researchers could take advantage of electronic devices to implement single-item digital visual scales for capturing variation in specific feeling states or dimensions of affect on rapid time scales (see Ram et al., 2011). As well, such devices would allow for more precise time-stamping and monitoring of compliance that could be done in the current study (Intille, 2007; Shiffman et al., 2008).

Evidence for the feel-good effect of physical activity has been well-established for many years. In sum, this study extended previous research on the feel-good effects of physical activity by specifying that free-time physical activity is specifically associated with pleasant-activated feeling states, that the association is present both between-persons and within-persons, and that the noted effect is not likely the result of the social calendar, sleep quality, or day-to-day carryover effects. With clarification of how daily free-time physical activity is

specifically associated with pleasant-activated feeling states, this study increased our understanding of relations between physical activity, mental health, and well-being.

Acknowledgments

We gratefully acknowledge the support provided by the National Institute on Aging (RC1 AG035645) and the Penn State Social Science Research Institute.

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Table 1
Descriptives, Intraclass Correlations, and Correlations of Free-Time Physical Activity, Feeling States, and Sleep Quality

	<i>M</i>	<i>SD</i>	<i>ICC</i>	1.	2.	3.	4.	5.	6.
1. Free-Time Physical Activity	12.47	10.51	.55	--	.13	.09	.02	.03	-.01
2. Pleasant-Activated Feeling States	3.93	1.17	.34	.09	--	.71	-.23	-.28	.32
3. Pleasant-Deactivated Feeling States	4.25	1.23	.36	.01	.61	--	-.5	-.36	.47
4. Unpleasant-Activated Feeling States	2.52	1.20	.35	-.03	-.29	-.48	--	.74	-.33
5. Unpleasant-Deactivated Feeling States	2.30	1.08	.38	-.11	-.34	-.27	.47	--	-.28
6. Sleep Quality	2.50	1.09	.25	.0001	.15	.21	-.21	-.12	--

Note. *ICC* = Intraclass correlation (proportion of between-person variance). *M* = sample-level mean, *SD* = sample-level standard deviation. Correlations of overall-level variables (e.g., OverallPhys) appear above the diagonal ($r > .14$, $p < .05$; $r > .19$, $p < .01$). Correlations of within-person daily variables (average within-person correlations of daily deviations, e.g., DailyPhys) appear below the diagonal. $N = 1,218$ days nested within 186 participants.

Table 2
Results of Multilevel Model Testing Daily Associations of Free-Time Physical Activity and Feeling States

Model	Estimate	SE	Model	Estimate	SE
Pleasant-Activated Feeling States					
Fixed Effects					
Intercept, γ_{00}	3.69*	0.10	Intercept, γ_{00}	2.52*	0.11
Daily Free-Time Physical Activity, γ_{10}	0.03*	0.01	Daily Free-Time Physical Activity, γ_{10}	-0.02	0.01
Overall Free-Time Physical Activity, γ_{01}	0.02*	0.01	Overall Free-Time Physical Activity, γ_{01}	0.0003	0.01
Overall X Daily Free-Time Physical Activity, γ_{11}	-0.001	0.001	Overall X Daily Free-Time Physical Activity, γ_{11}	0.001	0.001
Random Effects					
Intercept, σ^2_{u0}	0.47*	0.06	Intercept, σ^2_{u0}	0.51*	0.07
Daily Free-Time Physical Activity, σ^2_{u1}	-0.01	0.004	Daily Free-Time Physical Activity, σ^2_{u1}	0.0003	0.0003
Covariance, σ_{u0u1}	0.0002	0.0003	Covariance, σ_{u0u1}	0.001	0.003
Residual Variance, σ^2_e	0.86*	0.04	Residual Variance, σ^2_e	0.92*	0.04
Unpleasant-Activated Feeling States					
Fixed Effects					
Intercept, γ_{00}	4.05*	0.11	Intercept, γ_{00}	2.28*	0.10
Daily Free-Time Physical Activity, γ_{10}	0.02	0.01	Daily Free-Time Physical Activity, γ_{10}	-0.02	0.01
Overall Free-Time Physical Activity, γ_{01}	0.01	0.01	Overall Free-Time Physical Activity, γ_{01}	0.001	0.01
Overall X Daily Free-Time Physical Activity, γ_{11}	-0.001	0.001	Overall X Daily Free-Time Physical Activity, γ_{11}	0.0002	0.0005
Random Effects					
Intercept, σ^2_{u0}	0.59*	0.08	Intercept, σ^2_{u0}	0.46*	0.06
Daily Free-Time Physical Activity, σ^2_{u1}	0.0003	0.0004	Daily Free-Time Physical Activity, σ^2_{u1}	0.00	0.00
Covariance, σ_{u0u1}	0.0001	0.004	Covariance, σ_{u0u1}	-0.001	0.003
Residual Variance, σ^2_e	0.89*	0.04	Residual Variance, σ^2_e	0.70*	0.03

Note. Unstandardized estimates and standard errors. σ^2 = variance of random effects. N = 1,218 days nested within 186 participants.

* $p < .05$.

Table 3

Results of Multilevel Model Predicting Pleasant-Activated Feeling States by Free-Time Physical Activity and Potential Confounding Factors

	Estimate	SE
Fixed Effects		
Intercept, γ_{00}	2.84*	0.24
Daily Free-Time Physical Activity, γ_{10}	0.02*	0.01
Sunday, γ_{20}	-0.34*	0.09
Monday, γ_{30}	-0.46*	0.10
Tuesday, γ_{40}	-0.39*	0.10
Wednesday, γ_{50}	-0.43*	0.10
Thursday, γ_{60}	-0.25*	0.10
Friday, γ_{70}	0.10	0.10
Daily Sleep Quality, γ_{80}	0.17*	0.03
Previous Day Pleasant-Activated Feeling States, γ_{90}	0.01	0.03
Previous Day Free-Time Physical Activity, γ_{100}	-0.0004	0.004
Overall Free-Time Physical Activity, γ_{01}	0.02*	0.01
Overall X Daily Free-Time Physical Activity, γ_{11}	-0.0004	0.0005
Overall Sleep Quality, γ_{02}	0.44*	0.08
Random Effects		
Intercept, σ^2_{u0}	0.42*	0.06
Daily Free-Time Physical Activity, σ^2_{u1}	0.04*	0.02
Daily Sleep Quality, σ^2_{u2}	0.0002	0.0003
Previous Day Pleasant-Activated Feeling States, σ^2_{u3}	0.02	0.01
Previous Day Free-Time Physical Activity, σ^2_{u4}	0.00001	0.0002
Covariance, σ_{u0u1}	-0.01	0.003
Covariance, σ_{u0u2}	-0.02	0.02
Covariance, σ_{u0u3}	0.04	0.02
Covariance, σ_{u0u4}	-0.01	0.003
Covariance, σ_{u1u2}	0.001	0.002
Covariance, σ_{u1u3}	-0.001	0.002
Covariance, σ_{u1u4}	0.0004*	0.0002
Covariance, σ_{u2u3}	0.02	0.01
Covariance, σ_{u2u4}	0.0004	0.002
Covariance, σ_{u3u4}	-0.002	0.0002
Residual Variance, e_{dj}	0.75*	0.04

Note. Unstandardized estimates and standard errors. SE = Standard error. σ^2 = variance of random effects. $N = 1,218$ days nested within 186 participants.

*
 $p < .05$.