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Momentary Assessment of Affect, Physical Feeling States, and Physical Activity in Children

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Abstract

Objective—Most research on the interplay of affective and physical feelings states with physical activity in children has been conducted under laboratory conditions and fails to capture intraindividual covariation. The current study used Ecological Momentary Assessment (EMA) to bi-directionally examine how affective and physical feeling states are related to objectively-measured physical activity taking place in naturalistic settings during the course of children's everyday lives.

Methods—Children (N = 119) (ages 9–13 years) (52% male, 32% Hispanic) completed eight days of EMA monitoring, which measured positive affect (PA), negative affect (NA), feeling tired, and feeling energetic up to seven times per day. EMA responses were time-matched to accelerometer assessed moderate-to-vigorous physical activity (MVPA) in the 30 minutes before and after each EMA survey.

Results—Higher ratings of feeling energetic and lower ratings of feeling tired were associated with more MVPA in the 30 minutes after the EMA prompt. More MVPA in the 30 minutes before the EMA prompt was associated with higher ratings of PA and feeling energetic, and lower ratings

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of NA. Between-subject analyses indicated that mean hourly leisure-time MVPA was associated with less intraindividual variability in PA and NA.

Conclusions—Physical feeling states predict subsequent physical activity levels, which in turn, predict subsequent affective states in children. Active children demonstrated higher positive and negative emotional stability. Although the strength of these associations were of modest magnitude and their clinical relevance is unclear, understanding the antecedents to and consequences of physical activity may have theoretical and practical implications for the maintenance and promotion of physical activity and psychological well-being in children.

Keywords

positive affect; negative affect; fatigue; physical activity; ecological momentary assessment

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Despite accumulating evidence of the health benefits of regular physical activity (Strong et al., 2005), most children in the U.S. are physically inactive. Recent estimates suggest that only 40–50% of children 6–11 years of age and 6–11% of children 12–15 years of age engage in ≥60 minutes per day of moderate-intensity activity on at least 5 out of the past 7 days (Troiano et al., 2008). In order to address this problem, correlational and experimental studies have sought to identify cognitive, social, and environmental factors associated with physical activity among children (Ferreira et al., 2007; Van der Horst, Paw, Twisk, & Van Mechelen, 2007). However, the impact of these variables on physical activity has been limited, and many of the observed effects are modest in magnitude (Van Sluijs, McMinn, & Griffin, 2008). Thus, it may be fruitful to identify other psychosocial factors that play a role in physical activity among children.

There is growing interest in understanding the complex interrelationships between emotions, subjective physical feeling states (e.g., energetic arousal, fatigue), and physical activity in children. For instance, children who are more physically active tend to have lower levels of depressive symptoms (McDermott et al., 1990), and engaging in structured physical activity has been shown to reduce depression (Norris, Carroll, & Cochrane, 1992). Likewise, children report enhanced positive affect and feeling physically energetic, and reduced negative affect after structured exercise tasks (Schneider, Dunn, & Cooper, 2009). Plausible mechanisms underlying a beneficial affective response to physical activity include mood enhancement through biological pathways (e.g., beta-endorphins, endogenous opioids) (Dinas, Koutedakis, & Flouris, 2011; Grossman et al., 1984) and psychological processes (e.g., increased sense of achievement, self-esteem, self-efficacy) (Scully, Kremer, Meade, Graham, & Dudgeon, 1998).

Although these studies offer support for the effects of habitual and acute exercise on affective and physical feeling states, the question of whether affective and physical feeling states impact children's decisions to engage in physical activity remains unanswered. Emotional states are thought to play a central role in motivational processes underlying a variety of behaviors (Naqvi, Shiv, & Bechara, 2006), including those that promote physical health such as physical activity. For example, positive emotional states may influence health-relevant behaviors by engendering psychological resources (e.g., coping, social support) (Salovey, Detweiler, & Steward, 2000) or increasing appetitive motivation to participate in those behaviors (Updegraff, Gable, & Taylor, 2004). In contrast, negative emotions may trigger a motivational state of behavioral avoidance (Leone, Perugini, & Bagozzi, 2005), which could extend to multiple effortful behaviors, including physical activity. Thus, there may be a bi-directional association between affective states and physical activity. However, methodological weaknesses of past studies have restricted the capacity to test the effects of affective states on naturally-occurring physical activity levels in children.

A limitation of past research in this area is the reliance of structured exercise tasks in controlled laboratory settings to assess the association of exercise, affect, and physical feeling states. Participants are typically asked to perform a standardized exercise task such as riding stationary cycle or running on a treadmill for a specific intensity for a prescribed duration (Schneider et al., 2009). However, it has been shown that structured indoor physical activity causes greater perceived exertion (Bertucci, Grappe, & Groslamber, 2007) and is less psychologically restorative (Hug, Hartig, Hansmann, Seeland, & Hornung, 2009) than physical activity taking place in outdoor or naturalistic conditions. Thus, research is needed to understand how affective and physical feeling states may impact the choice to perform physical activity in free-living settings.

Another limitation of past research is the lack of focus on within-person differences in affective and physical feeling states. There is growing evidence suggesting that children’s affective and physical feeling states can vary considerably across each day (Axelson et al 2003; Larson & Lampman-Petraitis, 1989). Also, the degree of within-person (i.e., intraindividual) variability in affect over time is related to important physical and psychological health outcomes (Dumitrescu, Dogaru, & Dogaru, 2008; Weinstein, Mermelstein, Shiffman, 2008). Cross-sectional studies or intervention studies with pre-post measurements designs cannot adequately capture intraindividual variability (i.e., the degree of instability) in affective and physical feeling states.

These methodological weaknesses can be overcome with a real-time data capture strategy called Ecological Momentary Assessment (EMA). EMA obtains self-reports of psychological, affective, and behavioral variables during the course of everyday life (Bolger, Davis, & Rafaeli, 2003; Shiffman, Stone, & Hufford, 2008). In some modern EMA applications, mobile phones trigger the completion of brief electronic surveys through auditory signals programmed to occur at predetermined intervals throughout the day. Electronic surveys are time-stamped in order to be temporally linked to other types of data such as contemporaneous physical activity levels. Preliminary studies have used EMA to examine the associations of affective and physical feeling states with physical activity in adults (Dunton, Atienza, Castro, & King, 2009; Kanning, & Schlicht, 2010; Lepage, 2011; Schwerdtfeger et al., 2010; Wichers et al., 2012) and between affective states and other health behaviors such as smoking (Hedeker, Mermelstein, Berbaum, & Campbell, 2009) and caffeine consumption (Whalen et al., 2008) in children. Research has also used EMA to examine social and physical environmental influences on children’s physical activity (Dunton, Intille, Wolch, & Pentz, 2012; Dunton, Kawabata, Intille, Wolch, & Pentz, 2012; Dunton, Liao, Intille, Wolch, & Pentz, 2011). However, there is no published study capitalizing on EMA methodology to investigate linkages between affective and physical feelings states and physical activity in children.

The current study used EMA to examine how affective and physical feeling states are related to objectively-measured physical activity in children ages 9 to 13 years. In previous analyses of this sample (Dunton et al., 2011; Dunton, Intille, et al., 2012; Dunton, Kawabata et al., 2012), we focused on non-affective correlates of physical activity. The current paper reflects a unique contribution by focusing specifically on the relation of affective and feeling states to physical activity and attempts to elucidate affective mechanisms of physical activity in children. The first objective was to determine whether affective and physical feeling ratings at any given EMA prompt predict subsequent moderate-to vigorous physical activity (MVPA) in the 30 minutes after the prompt. It was hypothesized that more positive affect/feeling energetic and less negative affect/feeling tired at any given EMA prompt (relative to the child's own average level and other children) would predict more MVPA minutes measured in the 30 minutes following that EMA prompt. The second objective was to determine whether affective and physical feeling ratings at any given EMA prompt are predicted by MVPA in the 30 minutes before the prompt. We hypothesized that more MVPA minutes in the 30 minutes before any given EMA prompt (relative to the child's own average level and other children) would predict more positive affect/feeling energetic and less negative affect/feeling tired at the time of that EMA prompt. The third objective was to determine whether across the entire monitoring period, individual differences in intraindividual variability (i.e., degree of instability) in affective and physical feeling ratings are associated with mean hourly leisure-time MVPA. We expected that children with lower leisure-time MVPA would show greater instability in affective and physical feeling states. Physical activity may stabilize mood and/or emotionally unstable children may lack psychological resources or executive cognitive capacities (Zelazo & Mueller, 2002) necessary for planning, organizing, and participating in regular physical activity regimens. We explored gender as a moderator for all of the objectives listed above.

Method

Participants and Recruitment

Participants included ethnically-diverse children (9–13 years old) (N = 119) from primarily low to middle income households. The current study collected from a subgroup of children participating in a larger 4-year longitudinal study (Healthy PLACES), which is investigating the effects of the built environment on the prevention of family obesity risk. EMA data were only collected during the first year of the larger trial. Recruitment occurred through a variety of channels including informational flyers and letters distributed at community events, residences, schools, community health clinics, and churches. Parents were screened by phone to determine children's eligibility for the study. Inclusion criteria for both groups consisted of the following: a) lived in Chino, CA or within a 30-minute drive of Chino, CA, b) enrolled in the 4–8th grade, c) annual household income less than $165,000, and d) ability to complete questionnaires in English. Children who met the eligibility criteria were scheduled for a data collection appointment at a local community site or their home. This research was reviewed and approved by the Institutional Review Board at the University of Southern California. Parental consent and child assent were obtained.

Study Design

Each child participant completed two data collection waves (separated by six months) because the goal of the parent study was to examine changes in physical activity across time. However, physical activity levels did not differ between the first and second wave (Dunton, Intille, Wolch, & Pentz, 2012). Thus, we had no reason to suspect that our hypothesized associations would differ by wave, and data from both waves were included in the current analyses to improve the representativeness and reliability of physical activity and EMA data by increasing number of days sampled from four to eight days. No data collection took place from late July-August and during January due to the extreme temperatures and weather, which can alter physical activity patterns.

Protocol

This study used electronic EMA to measure affective and physical feeling states. EMA data were collected through a mobile phone (HTC Shadow, T-Mobile USA, Inc.) with a custom software program installed. The mobile phone calling and internet capabilities were disabled. Four days of EMA data were collected. Monitoring occurred during children's discretionary time from Fri. at 4pm to Mon. at 8:30pm with 20 auditory prompts (3–7 random prompts during preprogrammed intervals each day). No prompting occurred before 4pm on Monday during school hours. Upon hearing the signal, children were instructed to stop their current activity and complete a short electronic question sequence using the device. This process required about 2–3 min. If a signal occurred during an incompatible activity (e.g., sleeping, bathing), participants were instructed to ignore it. Children were compensated up to $40 for participating in the study: $20 plus an additional $1 for each completed EMA entry (20 total) over the 4 days.

Measures

EMA items—EMA question sequences measured current affective and physical feeling states as well as other behavioral and contextual variables that are reported elsewhere (Dunton, Kawabata, Intille, Wolch, & Pentz, 2012; Dunton, Liao, Intille, Wolch, & Pentz, 2011). Only one response could be provided for each item. The questions were administered in English. The EMA affect items were based partially upon the Positive and Negative Affect Schedule for Children (PANAS-C, Ebesutani et al., 2012; Laurent et al. 1999) and the results of previous EMA studies (Dunton et al., 2009). To assess positive affect (PA), participants were asked two items, "How (HAPPY, JOYFUL) were you feeling just before the beep went off?" Negative affect (NA) was assessed through four items, "How (STRESSED, MAD OR ANGRY, NERVOUS OR ANXIOUS, SAD) were you feeling just before the beep wet off?" Physical feeling states, FEELING TIRED and FEELING ENERGETIC (1 item each), were assessed in a similar fashion. Response options included "0 = Not at all," "1 = A little," "2 = Quite a bit," "3= Extremely." Scores for happy and joyful (2 items) were averaged to create a composite scale for PA (Cronbach's α = .87); and scores for sad, mad/angry, stressed, nervous/anxious (4 items) were combined for a composite NA scale (Cronbach's α = .74). To reduce participant burden, items measuring feeling energetic, feeling tired, PA and NA appeared in a randomly programmed 12 out of the 20 question sequences [60% of sequences]. All EMA items were thoroughly pilot tested in the target population for comprehension and applicability (Dunton et al., 2011).

Physical activity—The Actigraph, Inc. GT2M model activity monitors provided an objective measure of physical activity. The device was worn on the right hip attached to an adjustable belt. The devices were not worn when sleeping, bathing, or swimming. A 30-sec epoch was used. Moderate-to-vigorous physical activity (MVPA) was defined using age-specific thresholds generated from the Freedson prediction equation (≥4 Metabolic Equivalents) (METs) (Freedson et al., 1997; Freedson et al., 2005). The outcome variable was the number of minutes that were above the age-specific MVPA threshold. Accelerometer data were linked to EMA survey responses using the electronic time stamps. A SAS code recorded the number of MVPA minutes occurring within the 30-minute windows before and after each EMA survey response. Thirty-minute windows before and after EMA survey responses with a total of zero activity counts were considered accelerometer non-wear and excluded from the analyses. Mean hourly leisure-time MVPA (in minutes) was also calculated during the hours of EMA monitoring (4 – 8:30pm on Fridays and Mondays and 9am–4pm on Saturdays and Sundays). For the mean hourly leisure-time MVPA variable, strings of continuous recordings of zero activity counts lasting 60 minutes or more were considered accelerometer non-wear and excluded from analyses.

Height and weight—Children's height and weight were measured in duplicate using an electronically calibrated digital scale (Tanita WB-110A) and professional stadiometer (PE-AIM-101) to the nearest 0.1 kg and 0.1 cm, respectively. Body Mass index (BMI) percentile was calculated using CDC age- and gender-specific growth curves. Children were classified as underweight (less than 5^{th} percentile), at-risk for underweight (5^{th} –14^{th} percentile), normal weight (15^{th}–84^{th} percentile), at risk for overweight (85–94^{th} percentile), or overweight (95^{th} percentile or greater).

Demographics characteristics—Participants' age, sex, and race/ethnicity were assessed through a child self-report survey. Parents reported annual household income.

Data Analyses

Prior to analyses, patterns of unplanned missing data were evaluated to determine whether missingness was associated with any demographic characteristics. To examine the temporal effects of affective and physical feeling states on physical activity and vice versa (objectives #1 and #2), we conducted a series of mixed models using PROC MIXED (SAS version 10.0). The mixed models adjust the standard errors for clustering of observations within people (Raudenbush & Bryk, 2002). For the main predictor for each model, we generated both between-subject (BS) and within-subject (WS) versions (i.e., partitioning the variance) (Hedeker, Mermelstein, & Demirtas, 2008; Hedeker, Mermelstein, & Demirtas, 2012; Neuhaus & Kalbfleisch, 1998). The BS version represents a child's average level relative to the group mean for that variable (e.g., a child, on average, feels more energetic than the next child). The WS version represents the level at any given EMA prompt relative to his or her own average level across all EMA prompts (e.g., a child feels more energetic than his/her usual level at a given moment).

The third objective of this paper was to examine the associations of mean hourly leisure-time MVPA with intraindividual variability (i.e., instability) of children's affective and physical feeling states. With a mixed-effects location scale model using PROC NLMIXED (see Eq. 1), a random effect to the within-subject (WS) variance can be included (Hedeker et al., 2008). This allows for the WS variance to vary across individuals, controlling for the effects of covariates on the WS variance.

$$\sigma^2_{\varepsilon_{ij}} = \exp(w'_{ij}\tau + \omega_i) \quad \text{(Eq. 1)}$$

where *w* denotes a vector of time-varying predictors and τ stands for a vector of corresponding regression weights and ω represents a random effect. To test for the association of MVPA with instability in affective and physical feeling states, the direction, estimate and significance levels of the τ's in each model were examined. Each affective and physical feeling state was tested in a separate model. Additional models tested interactions of each of the predictor variables (both BS and WS versions) with gender.

Results

A total of 120 children participated in the first wave, and 101 of these children (85%) completed the second wave. Additionally, accelerometer data were not available for 9 children in the first wave and 8 children in the second wave due to technical problems with initializing and downloading data from the devices and accelerometer non-wear. Demographic characteristics for the participants with at least one wave of matched EMA and accelerometer data are shown in Table 1 (N = 119), which consisted of n = 114 children from wave 1 and n = 94 children from wave 2. On average, children responded to 34.8 out of 40 accelerometer-matched EMA survey prompts, resulting in an average compliance rate of 76% (range 24% – 100%). The percent of missed EMA responses per participant did not differ by sex, age, race/ethnicity, annual household income, or weight status. Fifteen percent of EMA data could not be matched to physical activity records due to accelerometer non-wear.

Available accelerometer-matched EMA data on affect and physical feelings states were as follows after taking into account randomly planned item missingness within each EMA survey: PA (n = 809 responses; M =1.8, SD = 0.92), NA (n = 822 responses; M =0.3, SD = 0.56), energy (n = 810 responses; M =1.4. SD = 1.03), and fatigue (n = 823 responses; M=0.8, SD = 0.84). Average MVPA within the 30-minute window before and after the EMA prompt was 1.1 min. (SD = 2.6) and 1.1 min. (SD = 2.5), respectively.

Table 2 shows the results of the mixed models testing the effects of affective and physical feeling ratings on the number of MVPA minutes occurring in the 30 minutes after the EMA prompt. Feeling more energetic than one's usual levels was associated with significantly more MVPA in the next 30 minutes (β = 0.46, p < .001). A significant gender x feeling energetic interaction was found (β = −0.52, p = .004), suggesting that these effects were weaker for girls than boys. Also, participants who felt more tired, as compared with other children, engaged in less MVPA in the next 30 minutes ($\beta = -0.38$, $p = .04$). PA and NA ratings at any given prompt were unrelated to subsequent levels of physical activity.

The results of the mixed models testing the effects of physical activity in the 30 minutes leading up to the EMA prompt on ratings affective and physical feeling ratings are displayed in Table 3. Engaging in more MVPA than a child's usual level led to feeling significantly more energetic ($\beta = 0.07$, $p <.001$) and PA ($\beta = 0.02$, $p = 049$) at the subsequent EMA prompt. The children with more MVPA minutes before the prompt on average, compared with other children, reported significantly lower levels of NA ($\beta = -0.08$, $p =.006$). MVPA was unrelated to feeling tired at the subsequent EMA prompt.

Table 4 shows the results of the mixed-effects location-scale models for affective and physical feeling states and mean hourly leisure-time MVPA. Mean hourly leisure-time MVPA was not correlated with mean scores for PA ($\beta = 0.01$, $p = .621$), NA ($\beta = -0.03$, $p = .057$), feeling energetic ($\beta = 0.01$, $p = .535$) or feeling tired ($\beta = -0.01$, $p = .687$). Children significantly differed from each other in their degree of intraindividual variability (BS var. in scale) in PA ($\tau = 0.42$, $p = .003$), feeling energetic ($\tau = .08$, $p = .011$) and feeling tired ($\tau = 0.53$, $p < .001$). The random scale portion of the model did not converge for NA. Children with greater mean hourly leisure-time MVPA, as compared with others, showed significantly less intraindividual variability in PA ($\tau = -0.09$, $p =.018$) and NA ($\tau = -0.06$, $p = .011$). Mean hourly leisure-time MVPA was unrelated to intraindividual variability in feeling energetic and feeling tired..

Discussion

Most research on the interplay of affective and subjective physical feelings states with physical activity in children has been conducted under controlled laboratory conditions, does not consider the bi-directional relation between feeling states and physical activity, and fails to capture intraindividual covariation. To overcome these weaknesses, the current study used EMA with electronic surveys displayed on mobile phones to examine how affective and physical feeling states are related to objectively-measured physical activity taking place in naturalistic settings during the course of children's everyday lives. Results indicated that children felt more energetic (relative to their own usual level) before and after greater physical activity. Interestingly, affective states (NA and PA) did not predict subsequent physical activity levels in a temporal manner. However, physical activity predicted immediate subsequent affective states. Also, more physically active children exhibited greater stability in PA and NA.

Results indicated that children's physical activity at any given moment was linked to prior physical feeling states. The regression models suggest that a 1-point increase in feeling energetic (on a 4-point scale), as compared with one's usual levels, would lead to a 0.5 minute increase in MVPA (about one fifth of a standard deviation) over the next 30 minutes. Also, a 1-point increase in feeling tired (on a 4-point scale), as compared with other children, would lead to a 0.4 minute decrease in MVPA (about two standard deviations) over the next 30 minutes. Although these effects are modest in magnitude, the accumulated effects of improved physical feeling states across the entire day could lead to an additional 15 minutes or more of physical activity. The deleterious effects of fatigue on physical activity engagement have been demonstrated in a number of studies (Kop et al 2005; Wendel-Vos, Schuit, Tijhuis, & Kromhout, 2004), and we extend these findings to real-time assessment in naturalistic settings. Results found that PA and NA ratings were unrelated to subsequent levels of physical activity, which stands in contrast to research in adults showing that affect predicts subsequent activity levels in a time-intensive fashion (Carels, Coit, Young, & Berger, 2007; Dunton et al., 2009; Schwerdtfeger, Eberhardt, Chmitorz, & Schaller, 2008). A limitation of this study was the inability of the EMA items to differentiate between physical activity performed through organized team sports or classes as compared with unstructured physically active free play. The effects could be attenuated by the inclusion of organized sports and classes. Participation in these activities may be more predicted by parental expectations or schedule or than prior affective and physical feeling states.

Results indicated that physical activity predicted subsequent affective and physical feeling states. The regression models suggested that a 14-minute increase in MVPA, as compared with one’s usual level, would lead to a 1.0 point (about one standard deviation) increase on the 4-point feeling energetic scale. Also, a 30-minute increase in MVPA, as compared with one’s usual level, would lead to a 0.26 point (about one-third of a standard deviation) increase in the 4-point PA scale. Although these effects are small in magnitude and their clinical relevance are not entirely clear, they are comparable to effects observed with adolescents and adults performing structured laboratory exercise tasks (Ekkekakis, Hall, & Petruzzello, 2008; Marakia et al., 2005; Miller, Bartholomew, & Springer, 2005; Woo, Kim, Kim, Petruzzello, & Hatfield, 2010). Proposed pathways underlying a positive affective response to physical activity include mood enhancement through the hormonal release of beta-endorphins or endogenous opioids (Dinas et al, 2011; Grossman et al., 1984) or psychological mechanisms such increased sense of achievement, self-esteem, and self-efficacy (Scully et al., 1998).

To the best of our knowledge, this study was the first to model stability in affective and physical feeling states as a function of mean physical activity levels in either children or adults. We found that PA and NA were more stable among children who more physically active during leisure time. However, mean levels of PA and NA were not associated with mean leisure-time physical activity. One potential explanation is that emotionally stable children have more psychological resources (e.g., coping mechanisms, self-esteem, optimism, subjective well-being) (Vitter, 2001) and higher executive functioning (Zelazo & Mueller, 2002), which could facilitate planning and participation in health-enhancing behaviors such physical activity. Weinstein and colleagues (2008) found that affect dysregulation, characterized by emotional instability, predicted an escalation in risky health behaviors such as smoking in adolescents. An alternative explanation is that physical activity fosters the development of executive functioning during late childhood and early adolescence through neurocognitive pathways (Tomporowski, Lambourne, & Okumura, 2011), which could enhance mood regulation capabilities. Future research should examine the longitudinal temporal relationships between physical activity participation and affective stability to clarify the causal direction of this association.

Findings from the current study may shed light on health behavior theory. Most health behavior theories focus on between-person differences in cognitive, attitudinal, and motivational factors (Glanz, Lewis, & Rimer, 2002). Consequently, the roles of transitory affective and physiological states have been overlooked (Dunton & Atienza, 2009). The explanatory value of theoretical health behavior models could be enhanced by taking into account multilevel interactions between enduring person-level factors and moment-to-moment level fluctuations in affective and physical feeling states to predict variability in the performance of a health behavior across the day (Riley et al., 2011). Results may also inform theories of health behavior maintenance. Accumulated affective and subjective physical responses to engaging in a health behavior over time could change one's general beliefs or attitudes towards performing the behavior in the future. Schneider and colleagues (2009) found that among adolescents, a more positive affective response during and after a structured exercise task was associated with greater participation in overall physical activity. Understanding how past behavioral experiences contribute to the likelihood of participating in future behavior has long been an interest of researchers studying behavior maintenance and habit formation (Ouelette & Wood, 1998; Wood & Neal, 2007). Recent work in this area suggests that satisfaction with the behavior, which may be influenced by rewarding experiences with the behavior itself or with the outcomes of the behavior, predicts behavior maintenance (Rothman, Sheeran, & Wood, 2009). Using EMA to capture real-time affective and physical responses to health behaviors such as physical activity may refine and advance these theoretical explanations of health behavior maintenance.

The results from the current study may also have methodological, practical, educational and clinical implications. To boost children's desire to be physically active, parents might take actions to reduce daytime tiredness such as enforcing a consistent bedtime and reducing children's intake of foods that lead to short energy bursts and crashes (e.g., simple carbohydrates, sugar-sweetened beverages, caffeine) (Spruijt-Metz et al., 2009). Furthermore, if physical activity leads to heightened physical arousal, children may be more receptive learners in educational settings after bouts of exercise. Research indicates that attention and cognitive functioning are enhanced by physical activity (Fisher et al., 2011) and physically active children perform better academically (Singh, Uijtdewilligen, Twisk, van Mechelen, & Chinapaw, 2012). In addition to its established physical health benefits, promoting physical activity in children is of interest because of its potential for enhancing psychological well-being. Acute positive affective responses to physical activity may lead to lower levels of depression and psychological distress among physically active children. Lastly, results from this study suggest that static measures of affect may not fully capture all of the affect-related variance in physical activity. Repeated assessment of affective factors to generate stability estimates may provide incremental predictive validity for identifying children who are at high risk for physical inactive lifestyles and may benefit most from physical activity interventions.

Despite the strengths of this study including the collection of real-time repeated measures data in naturalistic settings and the use of objective activity monitors, there are a few limitations that should be noted. Although the use of measures consisting of one to four items is not preferable, it is often necessary in EMA research in order to limit the length of each electronic survey to less than 2–3 minutes in order to enhance usability and reduce participant burden. Eight days of assessment may not be sufficient to represent children's usual behavior, Friday afternoons and evenings may not represent typical school days, and weekend days are overrepresented. However, longer monitoring periods at the current rate of survey prompting could impose participant burden and reduce compliance, especially in this younger population. Furthermore, the six–month lag in between each of the 4-day assessments may miss important change processes taking place during this period, and the aggregation of data across the two 4-day assessments may conceal nested sources of variation (e.g., seasonal). Also, this study only captured children's leisure-time physical activity. Activities taking place at school such as recess and physical education and active transport to and from school are not represented. Another concern is that the results represent affect during physical activity (i.e., children were engaging in physical activity at the time of the EMA prompt) instead of affect before or after activity. An ancillary analysis excluding occasions with EMA prompts answered during physical activity (i.e., five or more MVPA minutes in the ±15 minutes surrounding the EMA prompt) did not substantially change the size, direction, or significance of the coefficients. Also, the random scale portions failed to converge for negative affect and the mixed-effects location scale models testing gender interactions, most likely due to a lack of variance. Similar difficulties with model convergence have been noted when using PROC NLMIXED (Hedeker et al., 2008).

Overall, this study used EMA to examine the temporal sequealae of experiences leading up to and following physical activity in children. Results indicated that antecedents to higher levels of physical activity include feeling states (i.e., more energetic and less tired) whereas consequences of higher levels of physical activity include higher positive and lower affective states. Physically active children also demonstrated greater positive and negative emotional stability. Although the strength of these associations were of modest magnitude and their clinical relevance is unclear, these findings help to clarify our understanding of how affective and physical feeling states predict children's participation in physical activity. They also add to a growing body of literature on the physical and psychological benefits of physical activity.

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Table 1

Participant Characteristics

	n (%)
Sex	
Male	56 (49.1)
Female	58 (50.9)
Age	
9	13 (11.4)
10	30 (26.3)
11	32 (28.1)
12	28 (24.6)
13	11 (9.7)
Annual Household Income[a]	
Less than $45,000	29 (25.7)
$45,000–$79,999	33 (29.2)
$80,000–$99,999	26 (23.0)
$100,000 and above	25 (22.1)
Race/Ethnicity[b]	
African-American	11 (9.7)
Asian	15 (13.3)
Hispanic/Latino	36 (31.9)
White/Caucasian	25 (22.1)
Biracial/Mixed	19 (16.8)
Other	7 (6.2)
Weight Status	
Underweight (BMI < 5%)	5 (4.4)
At risk for underweight (BMI = 5–14%)	7 (6.1)
Normal weight (BMI = 15– 84%)	57 (50.0)
Overweight (BMI = 85–94%)	21 (18.4)
Obese (BMI ≥ 95%)	24 (21.1)

Note. N = 119. BMI = Body Mass Index.

[a]The parent of one child declined to report annual household income information.

[b]Race/ethnicity information was missing for one child.

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Table 2

The Association of Affective and Physical Feeling States with MVPA Minutes Occurring in the 30 Minutes After the EMA prompt

	MVPA	
	β (SE)	***p***
Positive Affect (PA) (*n* = 113)		
Intercept	1.23 (0.11)	<.001
BS	0.22 (0.19)	.248
WS	0.17 (0.11)	.136
Negative Affect (NA) (*n* = 116)		
Intercept	1.33 (0.13)	<.001
BS	−0.38 (0.34)	.260
WS	0.41 (0.22)	.060
Feeling Energetic (*n* = 114)		
Intercept	1.05 (0.09)	<.001
BS	0.21 (0.17)	.235
WS	0.46 (0.06)	<.001
Feeling Tired (*n* = 115)		
Intercept	1.03 (0.08)	<.001
BS	−0.38 (0.19)	.040
WS	−0.03 (0.07)	.686

Note. MVPA = moderate-to-vigorous physical activity. EMA = Ecological Momentary Assessment. BS = Between-subjects. WS = Within-subjects. Each variable was tested in a separate model.

Table 3

The Association of MVPA Minutes Occurring in the 30 Minutes Before the EMA Prompt with Affective and Physical Feeling States

	Positive Affect (PA) (*n* = 115)		Negative Affect (NA) (*n* = 117)		Feeling Energetic (*n* = 113)		Feeling Tired (*n* = 113)	
	β (SE)	*p*	β (SE)	*p*	β (SE)	*p*	β (SE)	*p*
MVPA								
Intercept	1.80 (0.06)	<.001	0.35 (0.04)	<.001	1.36 (0.05)	<.001	0.80 (0.04)	<.001
BS	0.05 (0.06)	.481	−0.08 (0.04)	.035	0.10 (0.05)	.060	−0.06 (0.05)	.190
WS	0.02 (0.01)	.049	0.00 (0.01)	.853	0.07 (0.01)	<.001	−0.00 (0.01)	.593

Note. MVPA = moderate-to-vigorous physical activity. EMA = Ecological Momentary Assessment. BS = Between-subjects. WS = Within-subjects. Each column represents a separate model.

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Table 4

Mixed-Effects Location-Scale Model for Affect and Physical Feeling State Variables and Mean Hourly Leisure-time Moderate-to-Vigorous Physical Activity (MVPA) in Minutes—Maximum Likelihood Estimates and Standard Errors

Positive Affect (PA)						
Parameter	**Mean β (SE)**	***p***	**BS var. α (SE)**	***p***	**WS var. τ (SE)**	***p***
Intercept	1.74 (0.10)	<.001	−1.10 (0.15)	<.001	−0.48 (0.14)	.001
Mean hourly leisure-time MVPA	0.01 (0.03)	.621			−0.09 (0.04)	.018
BS var. in scale					0.42 (0.14)	.003
Covariance (mean and WS var)					−0.15 (0.06)	.009

Negative Affect (NA)						
Parameter	**Mean β (SE)**	***p***	**BS var. α (SE)**	***p***	**WS var. τ (SE)**	***p***
Intercept	0.42 (0.05)	<.001	−2.44 (0.16)	< .001	−1.50 (0.09)	< .001
Mean hourly leisure-time MVPA	−0.03 (0.01)	.057			−0.06 (0.02)	.011
BS var. in scale					††	††
Covariance (mean and WS var)					††	††

Feeling energetic						
Parameter	**Mean β (SE)**	***p***	**BS var. α (SE)**	***p***	**WS var. τ (SE)**	***p***
Intercept	1.32 (0.09)	<.001	−1.48 (0.16)	<.001	−0.19 (0.08)	.014
Mean hourly leisure-time MVPA	0.01 (0.02)	.535			−0.002(0.02)	.909
BS var. in scale					0.08 (0.03)	.011
Covariance (mean and WS var)					−0.01 (0.02)	.743

Feeling tired						
Parameter	**Mean β (SE)**	***p***	**BS var. α (SE)**	***p***	**WS var. τ (SE)**	***p***
Intercept	0.82 (0.06)	<.001	−2.10 (0.17)	<.001	−0.56 (0.14)	<.001
Mean hourly leisure-time MVPA	−0.01 (0.02)	.687			−0.02(0.03)	.489
BS var. in scale					0.53 (0.13)	<.001
Covariance (mean and WS var)					0.20 (0.04)	<.001

Note. N = 119. BS = Between-subjects. WS = Within-subjects.

[††]The model with the addition of the random scale estimate (BS var. in scale) and estimate of covariance between random scale and location (mean and WS var) did not converge due to a lack of variance in the dependent variable.