Relationships among affective states, physical activity, and sedentary behavior in children: Moderation by perceived stress

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Abstract:

Objective: We examined the acute bidirectional relationships between affective states and moderate-to-vigorous physical activity (MVPA) or sedentary behavior (SB) in children, and whether perceived stress moderates these associations. Method: A total of 180 children (mean age = 9.6 years, 51.7% female, 53.9% Hispanic) completed a 7-day ecological momentary assessment (EMA) study, where they received 3–7 random prompts per day asking about their current affective states. MVPA and SB during this period were measured by waist-worn accelerometers. Children's and mothers' perceived stress were measured by paper questionnaires. Multilevel models tested the within-person (WP) and between-person (BP) associations of (a) MVPA and SB 30 and 60 min before an EMA prompt with subsequent affective states at the prompt, and (b) affective states at the prompt with MVPA and SB in the subsequent 30 and 60 min after the prompt. Interaction terms were used to assess whether children's and mothers' perceived stress moderated these associations. Results: Children reported a higher positive affect after engaging in more MVPA than usual (WP; $\beta = 0.04$, $SE = 0.02$, $p < .05$) and a lower positive affect after spending more SB than usual (WP; $\beta = -0.02$, $SE = 0.01$, $p < .05$) in the previous 30 min. Children's affective states were unrelated to time in MVPA and SB within the subsequent 30 min. Parent's perceived stress level attenuated the relationship between children's time spent in MVPA 60 min before a prompt and self-reported positive affect at that prompt ($\beta = -0.01$, $SE = 0.01$, $p < .05$). Conclusions: MVPA and SB acutely impacted children's psychological well-being, with the benefits of MVPA on positive affect across longer intervals attenuated among children whose mothers had higher perceived stress.

Keywords: exercise | emotions | stress | child | Ecological Momentary Assessment

Article:

Engaging in regular moderate-to-vigorous physical activity (MVPA) is associated with substantial improvements in both physical health (e.g., decreases adiposity; Lazaar et al., 2007) and mental health (e.g., reduces depression and anxiety; Biddle & Asare, 2011) and provides benefits across an individual's life span (Warburton, Nicol, & Bredin, 2006). Conversely, sedentary behavior (SB) is associated with various health risks (e.g., poorer mental health; Biddle & Asare, 2011) and increased depressive mood (Hoare, Milton, Foster, & Allender, 2016). Despite these documented health impacts, children and adolescents are still largely inactive (Troiano et al., 2008). Because these behaviors are likely to be carried through adolescence into adulthood (Telama et al., 2005), continuing efforts to promote MVPA and to reduce SB and for better understandings correlates of these behaviors in the pediatric population is necessary.

Among psychological correlates of MVPA, while cognitive factors have consistently demonstrated as determinants of MVPA (Cortis et al., 2017), emerging evidence has suggested the importance of understanding the bidirectional relationship between affect and MVPA engagement (Liao, Shonkoff, & Dunton, 2015). Affect is an individual's emotional experience occurring on a momentary basis that contributes to shaping long-term trait-like emotions (Barrett, 2017; Lazarus, 2001). MVPA has been shown to elicit affective response or change in affect in response to MVPA at various intensities (Ekkekakis, Hall, & Petruzzello, 2005). There also has been increasing interest in examining affective states that come from other sources (i.e., incidental affect) for their role in the motivational processes underlying various behaviors (Naqvi, Shiv, & Bechara, 2006), including subsequent MVPA engagement (Lyubomirsky, King, & Diener, 2005). In adult, studies have reported that MVPA predicts both positive (Emerson, Dunsiger, & Williams, 2017; Kanning, 2013; Liao, Chou, Huh, Leventhal, & Dunton, 2016) and negative affective states (Liao et al., 2015). In youth, Dunton and colleagues reported a similar affect-enhancing effect where children reported higher positive affect immediately following periods of greater MVPA (Dunton et al., 2014), suggesting that MVPA could elicit changes in affect. On the other hand, the predictive relationship between incidental positive affect and subsequent MVPA engagement has been reported in adults at the day level (Emerson et al., 2017; Niermann, Herrmann, von Haaren, van Kann, & Woll, 2016; Schöndube, Kanning, & Fuchs, 2016) and on a momentary basis (Liao, Chou, Huh, Leventhal, & Dunton, 2017). A similar predictive relationship has also been shown in children (Dunton et al., 2014). Nonetheless, the state of evidence on the bidirectional relationship between MVPA and affect in children is preliminary. Furthermore, null results have also been documented in the relationship between MVPA and subsequent affective response (Kanning, Ebner-Priemer, & Schlicht, 2015; Mata et al., 2012; von Haaren et al., 2013) and vice versa (Mata et al., 2012). Therefore, studies examining momentary associations between MVPA and affect and their moderators could improve our understanding of these relationships.

In youth, although SB has long-term detrimental effects on mental health (Biddle & Asare, 2011; Hoare et al., 2016), few studies have examined its immediate effects on affective response. Most existing evidence focuses on the effect of SB on long-term negative affect. In a recent trial, Endrighi, Steptoe, and Hamer (2016) colleagues showed that adults reported lower feelings of vigor and heightened anxiety, fatigue, and anger after spending 2 weeks in a sedentary condition, during which participants were asked to replace the usual MVPA with SB, compared with spending 2 weeks in their usual activity level. Investigating whether SB could predict subsequent affective response on a momentary basis in natural setting could improve ecological validity and elucidate how closely SB and affect are paired throughout the day. Similarly, the evidence base for the relationship between current incidental affect and subsequent SB is also limited. For youth, qualitative evidence indicates that children may consider some SB, such as screen time, enjoyable (Minges et al., 2015). Therefore, it is possible that incidental positive affective states can precede more SB engagement, because children may excitedly anticipate time to engage in upcoming leisure-time SB. Nonetheless, with the limited body of evidence, studies examining the acute psychological predictors of SB engagement are necessary.

Furthermore, as suggested by variation in observed effect sizes and mixed results across studies (Ekkekakis, Hargreaves, & Parfitt, 2013), there may be unexplored moderators in the bidirectional relationship between MVPA or SB and affective states. Perceived stress may influence individual's affective response to physical activity. A recent study by Stults-Kolehmainen and colleagues found that young adults who are chronically stressed exhibit a blunted affective response during strenuous exercise and a higher negative affect score 20-min postexercise (Stults-Kolehmainen et al., 2016). While individuals' affective response to strenuous exercise can be different from the affective response to other MVPA, it is possible that the bidirectional relationship between MVPA or SB and children's affect may be different among children who are more stressed. In addition, parents' perceived stress level could also influence children's affective states. Parents with high perceived stress exhibit higher nonsupportive responses to children (e.g., minimizing the child's emotion experience; Nelson, O'Brien, Blankson, Calkins, & Keane, 2009). Therefore, it is possible that children of more highly stressed parents may have dampened positive emotional responses to their own MVPA or SB engagement and vice versa.

To summarize, this study focused on examining the momentary bidirectional relationships between affective states and MVPA or SB using Ecological Momentary Assessment (EMA) among children in natural settings. Intensive longitudinal data collection strategies, such as EMA, can facilitate such investigation with an improved ecological validity (Shiffman, Stone, & Hufford, 2008) and the opportunities to examine the within-person differences in affective states and activity engagement. Affective states in children vary widely within each day (Axelson et al., 2003). Therefore, this approach could offer unique insights into the momentary effect of MVPA or SB engagement on affective states and vice versa that are otherwise challenging to assess in cross-sectional studies. Prior EMA studies have shown that the bidirectional relationship between incidental affective states and MVPA engagement exist in children on a timescale as short as 30-min in a suburban pediatric population (Dunton et al., 2014). This study seeks to investigate whether the bidirectional relationships persist in a 30-min and 60-min windows for both MVPA and SB and to further identify potential moderators of this bidirectional relationship in a metropolitan pediatric population. Specifically, we hypothesized that: (1) more time than a child's personal average spent in MVPA within 30 or 60 min window before a prompt would predict improved affective responses at the prompt (e.g., higher positive affect and lower negative affect), and that more time than a child's personal average spent in SB 30 or 60 min before a prompt would predict diminished affective states at the prompt (e.g., lower positive affect and higher negative affect); (2) incidental affective states at the prompt will predict subsequent MVPA or SB engagement in the subsequent 30 or 60 min; and (3) the predictive relationships between MVPA or SB engagement and subsequent affective responses are modified by perceived stress level, such that the bidirectional relationship between MVPA or SB and affect would be different among children who have higher levels of perceived stress or who live with a mother with higher levels of perceived stress.

Method

Participants

Data included in the current analysis were from the baseline wave of the Mothers' and Their Children's Health (MATCH) study, a longitudinal observational EMA study examining parenting factors and obesity in a sample of mothers and children. The full description of this study, including the rationale, detailed data collection strategies, and participant compliance, is presented elsewhere (Dunton et al., 2015). Briefly, participants were recruited via informational flyers and in-person research staff visit to public elementary school and community events. Participants were ethnically diverse mothers and their 8- to 12-year-old children living in the Los Angeles metropolitan area. The inclusion criteria for the mother–child dyads were as follows: (a) the child was in third through sixth grade; (b) the mother had ≥50% custody of the child; and (c) mother and child were able to read English or Spanish. Exclusion criteria were as follows: (a) either mother or child was currently taking medications for thyroid function or psychological conditions; (b) either mother or child had health issues that limited physical activity; (c) the child was enrolled in special education programs; (d) the child was currently using oral or inhalant corticosteroids for asthma; (e) the child had a body mass index (BMI; kg/m^2) below the fifth age- and sex- adjusted percentile; and (e) the mother worked more than 2 weekday evenings (between the hours of 5–9 p.m.) per week or more than 8 hours on any weekend day.

Procedures

Mothers provided informed consent and parental permission for the child to participate, and the child provided assent to participate in the study. Each dyad attended a 90-min data collection session at a local school or community center. During the session, the mother and the child each completed a battery of paper-and-pencil questionnaires, anthropometric assessments, were fitted with an accelerometer on the right hip, and received instructions on using the smartphone EMA application (app). EMA data were collected using a custom-made app for Android smartphones (Google Inc., Mountain View, CA) and were wirelessly uploaded and stored on a secure server for monitoring and documenting compliance. Research staff members contacted families by phone twice during the monitoring week to encourage compliance and to address technical issues. Children who owned Android smartphones were presented the option of downloading the app and completing the EMA prompts from their personal phones. Children without a compatible mobile phone were loaned a Moto G (Motorola Mobility, Chicago, IL) smartphone.

Across the following week, children responded to a maximum of 28 EMA prompts on the smartphone. Children received random EMA prompts after 5:00 p.m. on the day of the data collection session (Day 1), across the next 6 days (Days 2–7), and up until 5:00 p.m. on the last day when participants returned to researchers (Day 8). Each prompt included short questionnaires inquiring children's affective states and whether the participant engaged in specific eating (e.g., eating chips/fries) or activity (e.g., TV/video/video game or sports/exercise) behaviors during the previous 2 hr. The surveys were designed to be completed in 2–3 min. No prompts were scheduled to be delivered to the child participants during the school time (before 3:00 p.m. on weekdays). During the EMA monitoring period, participants were asked to carry the smartphone with the EMA app installed whenever is allowed (e.g., some schools prohibited students carrying cell phone during school hours) and proceed with their daily routines as normal. Upon receiving the prompts, children were instructed to stop their current activity and provide answers to a short EMA survey. If no entry was made, the app emitted up to two additional reminder signals at 3-min intervals and became inaccessible 3 min after the second reminder. Children were instructed to ignore prompt signals that occurred during incompatible activities (e.g., sleeping, bathing). Additional details regarding the EMA protocol has been previously published (Dunton et al., 2015).

In addition to the EMA surveys, the children were asked to wear an accelerometer (Actigraph model GT3X, Pensacola, FL) to measure MVPA and SB. Participants were instructed to wear the accelerometer on the right hip at all times, except for sleeping, bathing, or swimming. At the end of the monitoring period, each mother–child dyad received up to $200 for completing each week of assessment. Procedures were approved by the institutional review boards at the University of Southern California and Northeastern University. A more detailed description of the protocol for the MATCH study is published elsewhere (Dunton et al., 2015).

Measures

Affective states

Child's positive and negative affect were measured through EMA using a five-item positive and negative affect scale (Ebesutani et al., 2012). At each EMA prompt, participants were instructed to select from "*not at all*," "*a little*," "*quite a bit*," or "*extremely*" to five questions individually presented on separate screens as "Right before the phone went off, how happy/joyful/stressed/mad/sad were you feeling?" Children's positive affect at the prompt was calculated by averaging the scores for the "*happy*" and "*joyful*" items recorded in the same prompt (Cronbach's standardized alpha for the positive affect subscale: 0.922), and the negative affect was calculated by averaging the scores for the "*stressed*," "*sad*," and "*mad*" items recorded in the same prompt (Cronbach's standardized alpha for the negative affect subscale: 0.753).

Objective MVPA and SB

A waist-worn Actigraph accelerometer was set to collect time-stamped body movement data in activity count units for each 30-s epoch. The raw body movement data was downloaded using ActiLife v.6.11 (Actigraph, Pensacola, FL). Accelerometer data was used to calculate the number of minutes in MVPA and SB for each 30- or 60-min window before and after each EMA prompt. Only windows with at least 50% valid wear time (i.e., 15 min and 30 min of valid wear time for 30- and 60-min window) were included in this analysis. MVPA was defined using age-specific thresholds for children generated from the Freedson prediction equation equivalent to 4 Metabolic Equivalent Tasks (Belcher et al., 2010; Freedson, Pober, & Janz, 2005; Harrell et al., 2005; Laska, Murray, Lytle, & Harnack, 2012; Roemmich et al., 2000; Spruijt-Metz, Nguyen-Michel, Goran, Chou, & Huang, 2008). Time spent sedentary was defined as counts under 100 per minutes and was summed across 30- or 60-min window (Healy et al., 2008; Treuth et al., 2004). Accelerometer data and EMA data were linked using time-stamps and the number of

MVPA or SB minutes were summed across the 30-min windows both before and after each EMA prompt.

Self-reported MVPA and SB

At each EMA prompt, child participants were asked to self-report whether they have engaged in exercise/sports and SB during the past 2 hr prior to that EMA prompt. At each prompt, child participants were instructed to select "yes" or "no" to one question inquiring whether they have engaged in sedentary activity (i.e., engaged in TV/Video/Video game) and in sports (i.e., engaged in sports/exercise) during the past 2 hr.

Perceived stress

During the data collection session, mothers and children each completed a paper questionnaire where they reported on trait-like perceived stress in the past month. Mothers' perceived stress was assessed using the 10-item Perceived Stress Scale (PSS; Cronbach's alpha = .832) and was scored by summing the scores for all items after four items were reverse coded (Cohen, 1988). Child's baseline stress was assessed using the 21-item Stress in Children Scale (SiC, Cronbach's alpha = .585) and was scored by averaging the raw scores across all the items (Osika, Friberg, & Wahrborg, 2007).

Demographics and anthropometric measurements

At the baseline data collection session, children reported their age and sex. Mothers reported children's ethnicity (Hispanic vs. non-Hispanic). Height and weight were measured in duplicate using an electronically calibrated digital scale and professional stadiometer to the nearest 0.1 kg and 0.1 cm, respectively. Age- and sex-specific BMI *z* scores were calculated using Zanthro, a STATA program constructed based on EpiInfo (Vidmar, Carlin, Hesketh, & Cole, 2004).

Data Analyses

A series of multilevel models were conducted to examine the acute effect of (a) MVPA and SB in the 30 or 60 min leading up to child's affective states measured at the EMA prompt and (b) child's affective states at the EMA prompt on MVPA and SB in the 30 or 60 min subsequent to the EMA prompt. We generated both between-person (BP) and within-person (WP) versions (i.e., partitioning the variance) of the main predictor for each model. The BP effect is calculated by the child's person-mean of a predictor variable centered on the group mean of the same variable. The BP effect of the predictor variable represents an individual's average level of that predictor relative to the average of the other children in the study. The WP effect is calculated by subtracting child's level of the main predictor (e.g., level of MVPA in the 30-min window prior to an EMA prompt) at any given time of EMA sampling by the level of BP effect of that variable. The WP effect represents an individual child's level of the main predictor at any given occasion relative to that child's person-mean of the same variable across all his or her EMA prompts(Curran & Bauer, 2011).

To examine the momentary effect of MVPA and SB on subsequent affect, four separate models were constructed using either MVPA or SB in the 30- or 60-min windows prior to an EMA prompt as the predictor variables and either positive or negative affect as the outcome variable. Positive or negative affect score reported in the previous prompt (at the prior EMA prompting window of the same day) was controlled for in respective models with affective states as the outcome variable (i.e., positive affect in the previous prompt was included as a covariate in the model that predicts current MVPA). To examine whether affective state is associated with subsequent MVPA and SB, four models were constructed with minutes of MVPA or SB in the 30- or 60-min window after an EMA prompt as the outcome variable and either positive or negative affect variable as the predictor variable. Models with MVPA or SB as the outcome variables controlled for the time spent in that respective activity category in the 30- or 60-min before the prompt. The WP effect of the main predictor for each respective model was modeled as random effect.

A subsequent series of models tested mother and child baseline perceived stress as moderators of the affect-activity relationship. The moderator effects of children's and mother's perceived stress on the bidirectional relationships were assessed using two interaction terms constructed by multiplying the WP predictor variable with the (a) child's perceived stress score and (b) mother's perceived stress score. Both interaction terms were modeled as fixed effects. Post hoc exploratory analyses that examines the moderation effect of children's self-reported prior activity during the past 2 hr on the bidirectional relationships were assessed using interaction terms constructed by multiplying the WP predictor variable with (a) children's self-reported engagement in sedentary activity (i.e., engaged in TV/video/video game) and (b) children's self-reported engagement in sports (i.e., engaged in sports/exercise) during the past 2 hr.

All the models included child age, sex, and BMI percentile as covariates. Results of univariate analysis indicated that all the outcome variables met the normality assumptions except for the following: (1) minutes of MVPA 30 min after a prompt and (2) negative affect at the prompt. These two outcome variables were log-transformed prior to analyses. Because both the time in MVPA 30-min and 60-min after a prompt contain substantial amount of zeros (i.e., participants engaged in zero minute of MVPA 30-min or 60-min after a prompt), or in other words, zero-inflated, additional models using the two-part model approach were constructed for models with these variable as outcome of the models for comparison, as suggested by Baldwin and colleagues (Baldwin, Fellingham, & Baldwin, 2016). The results of the two-part model were similar and therefore was not reported. All data analyses were conducted using SAS v9.4 (Cary, NC).

Equations for Model 1: (Time Spent in Activity [MVPA or SB] in Prior 30-/60-min Predicting Current Affect)

Level 1:

$$Affect_{ti} = \beta_{0i} + \beta_{1i}(Activity_{wpt-1i}) + \beta_{2i}(Affect_{t-1i}) + e_{ti}$$

Level 2:

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(Activity_{bpi}) + \gamma_{02}(Chronic\ Stress_{Childreni})$$
$$+ \gamma_{03}(Chronic\ Stress_{Motheri}) + \gamma_{04}(Age_i) + \gamma_{05}(Gender_i)$$
$$+ \gamma_{06}(BMI\%ile_i) + \mu_{0i}$$
$$\beta_{1i} = \gamma_{10} + \gamma_{01}(Activity_{bpi}) + \gamma_{12}(Chronic\ Stress_{Childreni})$$
$$+ \gamma_{13}(Chronic\ Stress_{Motheri}) + \mu_{1i}$$
$$\beta_{2i} = \gamma_{20}$$

Equations for Model 2: (Current Affect Predicting Time Spent in Activity [MVPA or SB] in Subsequent 30-/60-min)

Level 1:
$$Activity_{ti} = \beta_{0i} + \beta_{1i}(Affect_{wpt-1i}) + \beta_{2j}(Activity_{t-1i}) + e_{ti}$$

Level 2:
$$\beta_{0i} = \gamma_{00} + \gamma_{01}(Affect_{bpi}) + \gamma_{02}(Chronic\ Stress_{Childreni})$$
$$+ \gamma_{03}(Chronic\ Stress_{Motheri}) + \gamma_{04}(Age_i) + \gamma_{05}(Gender_i)$$
$$+ \gamma_{06}(BMI\%ile_i) + \mu_{0i}$$
$$\beta_{1i} = \gamma_{10} + \gamma_{01}(Affect_{bpi}) + \gamma_{12}(Chronic\ Stress_{Childreni})$$
$$+ \gamma_{13}(Chronic\ Stress_{Motheri}) + \mu_{1i}$$
$$\beta_{2j} = \gamma_{20}$$

Results

Descriptive Statistics

Overall, 202 mother–child dyads participated in the data collection. Of the 202 children, 22 participants who did not provide any response to EMA prompts were excluded. Table 1 shows demographic information for the full sample (N = 202) and the final analytic sample (N = 180). There were no statistically significant differences in key participant demographics between the full and analytic samples. Children included in the analytic dataset ranged in age from 8–12 years old (M= 9.6, SD = 0.92) and in BMI percentile from 4.1–99.6 (M = 64.5, SD = 29.25). Approximately half of the children were female (51.67%) and of Hispanic or Latino origin (53.9%). Approximately two thirds (67.2%) of the mothers in the study sample were married. The score for children's perceived stress at baseline ranged from 1.24–3.76 (M = 1.96, SD = 0.35 on a possible 1 to 4 scale) and the score for mother's perceived stress ranged from 4–30 (M = 14.69, SD = 5.35 on a possible 0 to 30 scale). The baseline child and mother perceived stress scores were low, but marginally significantly correlated with each other (Pearson r = .138, p = .066). During the EMA monitoring period, the children participants responded to, on average, 74.43% (SD = 19.89, range = 10.0%–100.00%) of the prompts. The compliance rate was not related to demographic characteristics (age, gender, ethnicity, and BMI percentile).

Table 1. Participant Characteristics

Variable	M ± SD: Full dataset (N = 202)	Analytic dataset (n = 180)
Child age	9.61 ± .91 (n = 202)	9.61 ± .92 (n = 180)
Mother age	40.94 ± 6.13 (n = 201)	41.00 ± 6.01 (n = 179)
Child BMI percentile	64.36 ± 28.87 (n = 195)	64.46 ± 29.25 (n = 173)
Gender (female %)	50.99%	51.67%
Child Hispanic origin	53.96%	53.89%
Mother Hispanic origin	49.01%	47.78%
Mother education	(n = 196)	(n = 174)
High school	16.32%	14.37%
College	59.18%	60.34%
Post graduate	24.49%	25.29%
Family income level (USD)	(n = 201)	(n = 179)
$0–$34,999	27.37%	26.82%
$35,000–$74,999	29.36%	29.03%
$75,000–$100,499	19.42%	17.11%
$100,500+	23.89%	24.03%
Mother employment	(n = 199)	(n = 177)
Full-time	56.78%	57.63%
Part-time	24.62%	24.86%
Not in workforce (unemployed, student, home parents, retired)	16.58%	15.81%
Others	2.01%	1.69%

Note. BMI = body mass index.

Across all the answered EMA prompts, the children reported an average positive affect of 2.06 (*SD* = 0.94, range = 0–3) and negative affect of 0.26 (*SD* = 0.50, range = 0–3). The study participants spent an average of 1.83 min (*SD* = 3.93, range = 0–30) in MVPA and 12.14 min (*SD* = 9.55, range = 0–30) in SB within the 30-min window *before* a prompt and an average of 3.64 min (*SD* = 7.16, range = 0–60) in MVPA and 24.04 min (*SD* = 17.85, range = 0–60) in SB within the 60-min window *before* a prompt. The study participants spent an average of 1.78 min (*SD* = 3.88, range = 0–30) in MVPA and 12.42 min (*SD* = 9.64, range = 0–30) in SB within 30 min *after* a prompt and an average of 3.46 min (*SD* = 6.94, range = 0–60) in MVPA and 24.82 min (*SD* = 17.85, range = 0–60) in SB within 60 min *after* a prompt. Descriptive statistics of the participants are presented in Table 1.

Prior MVPA and SB Predicting Current Affective State

Results of the multilevel models examining the effects of MVPA and SB in the 30 min and 60 min prior to an EMA prompt on affective state measured at that prompt are presented in Table 2. The results indicated that, relative to their own average, children reported higher positive affect scores only after they had spent more time in MVPA in the previous 30 min (Model 1a: WP-MVPA $\beta = 0.04$, $SE = 0.02$, $p < .05$), not 60 min (Model 1b). No association between WP-MVPA in the previous 30 or 60 min and negative affect (Model 2a and 2b) was identified. Mother's baseline perceived stress moderated the relationship between time spent in MVPA 60 min before a prompt and positive affect (Model 1b). Both baseline perceived stress score did not moderate the relationship between MVPA 30 min before a prompt and positive (Model 1a) or negative affect (Model 2a) and the relationship between MVPA 60 min before a prompt and negative affect (Model 2b).

Table 2. Time in Moderate-to-Vigorous Physical Activity (MVPA) or Sedentary Behavior (SB) 30 or 60 Min Prior to a Prompt Predicting Current Affective States at a Prompt

Independent variables	Dependent variable, β (*SE*)		Independent variables	Dependent variable, β (*SE*)	
	Model 1a: Positive affect at prompt	Model 2a: Negative affect at prompt		Model 1b: Positive affect at prompt	Model 2b: Negative affect at prompt
Intercept	1.08 (.27)**	.34 (.59)	Intercept	1.09 (.27)**	−.33 (.49)
WP time in MVPA 30 min prior to a prompt	.04 (.02)*	−.01 (.04)	WP time in MVPA 60 min prior to a prompt	.02 (.01)	.02 (.02)
BP time in MVPA 30 min prior to a prompt	−.01 (.01)	.04 (.02)	BP time in MVPA 60 min prior to a prompt	−.01 (.05)	.02 (.01)
Mother's perceived stress	*.10 (.04)**	*.002 (.10)*	Mother's perceived stress	.09 (.04)*	.08 (.08)
Child's perceived stress	−.48 (.08)**	.13 (.17)	Child's perceived stress	−.47 (.08)**	.02 (.14)
WP MVPA * Mother's Perceived Stress	−.02 (.01)	.01 (.03)	WP MVPA * Mother's Perceived Stress	−.01 (.01)*	−.01 (.01)
WP MVPA * Child's Perceived Stress	.03 (.02)	.04 (.12)	WP MVPA * Child's Perceived Stress	.01 (.01)	−.01 (.06)
	Model 3a: Positive affect at prompt	Model 4a: Negative affect at prompt		Model 3b: Positive affect at prompt	Model 4b: Negative affect at prompt
Intercept	1.10 (.27)**	.60 (.57)	Intercept	1.07 (.27)	.21 (.43)
WP time in SB 30 min prior to a prompt	−.02 (.01)*	−.02 (.02)	WP Time in SB 60 min prior to a prompt	−.01 (.01)	−.00 (.01)
BP time in SB 30 min prior to a prompt	−.01 (.01)	−.01 (.01)	BP time in SB 60 min prior to a prompt	.00 (.00)	−.01 (.01)
Mother's perceived stress	.05 (.05)	−.05 (.10)	Mother's perceived Stress	.04 (.05)	−.10 (.07)
Child's perceived stress	−.49 (.08)*	.24 (.20)	Child's perceived Stress	−.47 (.08)**	.09 (.16)
WP SB * Mother's Perceived Stress	.01 (.01)	.01 (.01)	WP SB * Mother's Perceived Stress	.01 (.003)	−.000 (.01)
WP SB * Child's Perceived Stress	− .05 (.01)	− .03 (.02)	WP SB * Child's Perceived Stress	− .00 (.01)	.002 (.01)

Note. WP = within-person; BP = between-person. All models adjusted for age, gender, body mass index (BMI) percentile, minutes of MVPA or SB within 30 or 60 min of the prompt, and chronological prompt number. Only windows with more than 50% valid wear were included.
$^*p < .05$. $^{**}p < .01$.

The effects of SB on children's subsequent affective states were examined, children who had more SB in the 30 min prior to a prompt, relative to their own average, reported lower positive affect scores at that prompt (Model 3a: WP-SB: $\beta = -0.02$, $SE = 0.01$, $p < .05$). No association was observed between WP-SB in the 60 min prior to a prompt and positive affect (Model 3b). No association was observed between WP-SB during the previous 30 or 60 min and negative affect (Model 4a and b). Mother's and child's baseline perceived stress did not moderate the relationship between prior SB and positive (Model 3a and b) or negative affect (Model 4a and b).

Exploratory analyses that examined whether the participants' self-reported activities during the past 2 hr (e.g., engage in TV/video/video game and sports/exercise during) moderate the relationship between MVPA or SB 30 or 60 min prior and affective state at the prompt were conducted on a post hoc basis. The aforementioned relationships did not differ after adjusting for self-reported prior SB and exercise. The within-person relationships between prior time spent in MVPA or SB and subsequent affective state were not moderated by children's self-reported activities (data not reported).

Current Affective State Predicting Subsequent MVPA and SB

Both multilevel models and two-part models were conducted to examine the association between current positive or negative affect and MVPA or SB in the 30- and 60-min window immediately following an EMA prompt. There was no statistically significant association between current affective states and MVPA (Table 3; Model 5a and 6a) or SB (Table 3, Model 7a and 8a) in the subsequent 30 min or 60 min (MVPA: Model 5b and 6b; SB: Model 7b and 8b). Neither mothers' nor children's baseline perceived stress modified these associations.

Table 3. Affective States Predicting Moderate-to-Vigorous Physical Activity or Sedentary Behavior 30 or 60 Min After a Prompt

Positive affect predicting MVPA or SB 30 or 60 min after a prompt				
	Dependent variable, β (*SE*)			
	Time in MVPA		Time in SB	
Time frame	Model 5a: In the next 30 min	Model 5b: In the next 60 min	Model 6a: In the next 30 minutes	Model 6b: In the next 60 minutes
Intercept	1.31 (.19)**	2.22 (.28)**	7.04 (1.84)**	14.36 (3.8)**
WP Positive affect	.10 (.12)	.16 (.10)	−.23 (.68)	.27 (1.39)
BP Positive affect	−.03 (.03)	−.07 (.04)	−.03 (.26)	−.36 (.54)
Mother's perceived stress	−.02 (.03)	−.03 (.07)	−.76 (.32)*	−1.21 (.66)
Child's perceived stress	−.12 (.06)*	−.19 (.08)*	−.76 (.53)	−1.87 (1.10)
WP Positive Affect * Mother's Perceived Stress	−.04 (.04)	−.07 (.06)	.19 (.42)	−.09 (.86)
WP Positive Affect * Child's Perceived Stress	−.08 (.06)	−.16 (.08)	.03 (.60)	−.62 (1.23)

Negative affect predicting MVPA or SB 30 or 60 min after a prompt				
	Time in MVPA		Time in SB	
Time frame	Model 7a: In the next 30 min	Model 7b: In the next 60 min	Model 8a: In the next 30 min	Model 8b: In the next 60 min
Intercept	1.08 (.21)**	1.96 (.30)**	6.44 (1.95)**	12.61 (4.22)**
WP Negative affect	−.05 (.10)	−.24 (.14)	−1.07 (1.03)	−1.06 (2.13)
BP Negative affect	.01 (.07)	.01 (.10)	.84 (.65)	.95 (1.41)
Mother's perceived stress	−.003 (.04)	−.02 (.05)	−.63 (.34)	−.93 (.73)
Child's perceived stress	−.06 (.06)	−.09 (.08)	−.61 (.53)	−1.24 (1.14)
WP Negative Affect * Mother's Perceived Stress	.05 (.06)	.12 (.09)	.60 (.64)	.54 (1.32)
WP Negative Affect * Child's Perceived Stress	.04 (.09)	.13 (.12)	.19 (.90)	−.33 (1.87)

Note. WP = within-person; BP = between-person. All models adjusted for age, gender, body mass index (BMI) percentile, minutes of MVPA or SB within 30 or 60 min of the prompt, and chronological prompt number. Only windows with more than 50% valid wear were included.
*$p < .05$. **$p < .01$.

Discussion

This study investigated the momentary bidirectional relationships between MVPA and SB and affect in children and examined the potential moderating role of perceived stress in this bidirectional relationship in this group of children from a large metropolitan area. Consistent with the literature (Dunton et al., 2014), children reported an improved positive affect after spending more time in MVPA than their personal average during the previous 30 min. In addition, children reported lower positive affect after they have engaged in more SB than usual in the previous 30 min. These relationships, however, were not observed in models that examined the within-person relationship between times spent in MVPA or SB within the 60-min window prior to an EMA prompt. However, contrary to the existing literature, results of the current study did not support the predictive relationship between children's positive or negative affective states and the amount of time spent in MVPA or SB in the subsequent 30 or 60 min. Because both MVPA and SB were found to be related to subsequent positive affect on a momentary basis, independent of both mother's and child's own perceived stress level, the study results highlight the potential role of MVPA and SB in promoting children's psychological well-being.

Findings from the current study, consistent with existing studies in youth (Dunton et al., 2014) and other age groups (Liao et al., 2017), indicate that MVPA engagement is associated with an improved subsequent positive affect in children at a within-person level, regardless of whether the MVPA captured for that moment is part of a coherent bout of activity. Children engage in MVPA in a more sporadic and intermittent pattern than adults (Armstrong & Bray, 1991; Mark & Janssen, 2009) and that achieving 10 or more consecutive minutes of MVPA is infrequently observed in children. In this study sample, 77.2% and 46.7% of participants had zero or only one bout of MVPA over 10 min long at 30 and 60 min prior to a prompt throughout the 7-day EMA monitoring period, respectively. Because current evidence suggests that both sporadic MVPA (<5 consecutive minutes of MVPA) and longer bouts (10 + consecutive minutes of MVPA) have similar health benefits for youth (Holman et al., 2011; Poitras et al., 2016), results of this study could be used to expand the current literature on the emotional health benefits of MVPA. Results from the regression models also suggest that, compared with a child's usual activity level, a 13-min increase in MVPA at any given 30-min window in free-living environment during the day could lead to more than 0.5 points (or over half of one standard deviation) increase in the positive affective state score on a 4-point scale. This magnitude of effect is comparable to study in other children populations (Dunton et al., 2014) and adult populations (Ekkekakis, Hall, & Petruzzello, 2008). While MVPA could improve affective states through physiological pathways (e.g., beta-endorphins (Dinas, Koutedakis, & Flouris, 2011), this change in positive affective states and the null relationship between prior MVPA and negative affective states could also be a consequence of children spending more time in activities that they enjoyed at the moment (Kanning, 2013). Because this predictive relationship persists independent of children and parent's perceived stress level, results of this study highlight the important benefits of MVPA on children's psychological well-being. This study has further identified the predictive relationship between SB and a lowered positive affective state in children. The mechanism through which SB influences positive affective states is yet unclear. However, it is possible that behaviors requiring school-age children to be sedentary for longer than their average level (e.g., homework, time in class) are not as pleasurable as other leisure-time SBs (e.g., watching TV). While further study is necessary to untangle the processes through which SB predict subsequent affective states, this study provides preliminary evidence indicating that SB reduced positive affect.

Contrary to the study hypotheses, the relationship of MVPA or SB on affective states in the subsequent 30 min was not modified by perceived stress levels of the children and the parents. Interestingly, however, mother's perceived stress levels moderated the relationship between MVPA and positive affect in the subsequent 60 min, such that the positive effects of MVPA on subsequent positive affect were diminished among children whose mothers reported higher levels of perceived stress. Because mother's perceived stress may impact parental supportive behaviors (Nelson et al., 2009), it is possible that the positive experience after engaging in MVPA can be different among children whose mother is more stressed. The emergence of the moderated effect of mother's baseline perceived stress on the linkage between MVPA and positive affect only for the 60-min window suggests that mothers' chronic stress may attenuate effects of longer (rather than shorter, as in within a 30-min window)-lasting affective responses to MVPA. While the moderator effect is observed only at the 60-min interval, this result supports the notion that parent's stress has an obesogenic role in children (Tate, Wood, Liao, & Dunton, 2015).

This study expands upon the understanding of the current bidirectional relationships between children's affective state and MVPA by utilizing real-time repeated measurement of children's affective states and objectively measured MVPA and SB in a natural environment. Despite the various strengths of this study, there are also several limitations. First, the current analysis did not statistically examine context as a time-varying moderator. Because prior evidence in adults suggests that affective response to MVPA can differ by whether an individual is alone or outdoors (Dunton et al., 2015), further investigation of time-varying moderators of the observed associations is needed. Second, while this study shows that both spending more time in MVPA and SB 30 min prior to an EMA prompt are associated with subsequent positive affect, the change in affect could be a mixture of integral (i.e., affect as a result of MVPA engagement) and incidental affect (i.e., affect outside of the context of MVPA). In addition, it is yet unclear whether this effect is universal to different kinds of MVPA, for example, team-based (e.g., basketball) versus individual-based (e.g., running) MVPA, or SB, for example, SB of leisure-purpose (e.g., watching TV) versus nonleisure purpose (e.g., homework). Furthermore, results of the current study are only generalizable to activities able to be captured by accelerometers. The limited abilities of waist-worn accelerometers in detecting activities that involves only limbic movements (e.g., cycling and weight lifting), accounting for the additional energy associated with an inclined surface, and measuring activities that occur during protocol-directed nonwear times (e.g., swimming) are well-documented (Butte, Ekelund, & Westerterp, 2012; Trost & O'Neil, 2014). Therefore, future studies that improve on these limitations can further elucidate the affect-promoting effect of MVPA. Third, results of this study are based on data collected around the time when EMA prompts were sent, which were mostly outside of school and during later afternoon or early evening. While this data collection schedule allowed for investigations on bidirectional relationships between affective states and MVPA or SB in free-living environment, whether the same relationships can be generalized to MVPA or SB occurring during school remains unclear. MVPA or SB that occurs at school may impact children's subsequent affective states differently from MVPA or SB in free-living environment. For instance, participation in MVPA as a result of a required activity (e.g., physical education class) may be different from the affective experiences from engaging in freely chosen MVPA during leisure time. Therefore, future studies in these settings could further elucidate the nuanced relationship between MVPA or SB engagement and subsequent affective states in children. Last, as the study participants were elementary schoolchildren living in an urban U.S. metropolitan region, future studies focusing on youths in other age groups or regions would expand the current state of evidence in the momentary bidirectional relationships between affective states and activities and its moderators.

In summary, this study uses data collected using a novel methodology with EMA and accelerometers to examine the acute bidirectional effect among children's MVPA, SB, and affective states and is the first study investigating this relationship using data from the MATCH study. Although previous studies have examined the bidirectional effect between objectively measured activity level (MVPA and SB) and affective states, few have been conducted in children and none have investigated the effect of trait stress of self and/or mother as a moderator. Both within-person MVPA and SB were acutely associated with children's subsequent incidental positive affective states, regardless of children's own self-reported prior SB or MVPA engagement, respectively. These findings suggest the importance of these behaviors on a child's immediate subsequent affect, which has shown to be an important predictor for long-term behavior adherence (Williams & Evans, 2014), including MVPA (Schneider, Dunn, & Cooper, 2009). Also, results of this study could be used to inform intervention and educational programs to help children cope with moments of emotional distress. The within-person association identified in this study highlights the acute positive emotional health benefits of engaging in MVPA. Building from these results, interventions seeking to bolster children's capacities for emotional regulation may encourage children to find ways to be physically active during times of emotional distress to boost momentary positive affect. In the flip side, results showing that sedentary behaviors are associated with acute reductions in positive affect suggest that emotional regulation interventions for children to encourage children to avoid screen time and other types of sedentary behaviors in moments of distress. Equally importantly, results of this study highlight the importance of managing mothers' stress in fostering children's affective experience. Results of this study highlight that maternal stress management could potentially improve children's experience associated with being physically active, which in turn could promote future MVPA engagement. While results of this study highlight the contribution of MVPA and SB to children's subjective mood states, future studies that examines the effect of father's perceived stress and other salient family level mediators and moderators (such as parenting practices) of this relationship are necessary to fully understand the mechanism underlying that could promote and sustain children's MVPA engagement.

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