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Does context predict psychological states and activity? An ecological momentary assessment pilot study of adolescents

Carolina M. Bejarano[a], Christopher C. Cushing[a,b,*], Christopher J. Crick[c]

[a] Clinical Child Psychology Program, University of Kansas, 1000 Sunnyside Avenue, Lawrence, KS 66045, USA
[b] Clinical Child Psychology Program & Schiefelbusch Institute for Life Span Studies, University of Kansas, 1000 Sunnyside Avenue, Lawrence, KS 66045, USA
[c] Computer Science Department, Oklahoma State University, 219 MSCS, Stillwater, OK 74078, USA

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ABSTRACT

Objectives: This study examined contextual variables of location, vegetation, weather, safety, and traffic as predictors of affect, feeling states, and activity in order to gain preliminary understanding of relationships relevant to adolescent health.
Design: This is an ecological momentary assessment pilot study of adolescents.
Method: Twenty-six adolescents ages 13–18 completed four daily surveys on a smartphone and wore an accelerometer over 20 days. Surveys collected data about context, affect, and feeling states while the accelerometer provided objective activity measurements.
Results: Significant relationships emerged between weather and MVPA, sedentary behavior, positive affect, negative affect, energy, and fatigue. Findings were also significant for the contextual predictor of location with sedentary behavior, positive affect, negative affection, energy, and fatigue. Within-person (WP) vegetation was associated with positive affect and energy and WP traffic was associated with positive affect, negative affect, and energy. WP safety and between-person safety were both significantly related to negative affect.
Conclusions: Ecological momentary assessment of contextual variables may be important in understanding these variables' associations with psychological and activity variables, and should continue to be measured in this way to inform comprehensive health behavior models.

Engagement in physical activity offers a host of positive physical and psychosocial benefits (e.g., healthy weight status, self-esteem) while spending excess time in sedentary activities is associated with many negative effects on health and well-being (e.g., increased risk for cardiovascular disease, depressive symptoms; Iannotti & Wang, 2013; Office of Disease Prevention and Health Promotion [ODPHP], 2017; Rachele, Cuddihy, Washington, & McPhail, 2014). According to national reports, less than 25% of youth get the recommended 60 min of daily physical activity, and typically engage in too much sedentary behavior (e.g., less than 40% of youth follow recommendations for > 2 h of daily screen time; Katzmarzyk et al., 2016). These concerning patterns tend to worsen in adolescence (ODPHP, 2017; Porter, Matthews, Salvo & Kohl, 2017).

1. Ecological momentary assessment of between- and within-person processes

Research indicates that a variety of internal and external forces interact to influence whether an individual's behavior is active vs. sedentary (Baranowski, Perry, & Parcel, 2002; Sallis, Owen, & Fisher, 2015). Both these internal and external forces can vary within individuals, such as an adolescent feeling more fatigued on some days as compared to other days, as well as between individuals, such as an adolescent generally spending more time outdoors than another adolescent typically spends. Because these factors have the potential to vary, it is important to understand them with use of repeated measurements, such as through ecological momentary assessment (EMA; Heron, Everhart, McHale, & Smyth, 2017). By capturing assessments of the constructs repeatedly, it is possible to estimate each person's average level and to model deviations from that average as a fluctuating value. Such a conceptualization is particularly useful in the study of

Abbreviations: MVPA, Moderate to Vigorous Physical Activity; EMA, Ecological Momentary Assessment; JITAI, Just-In-Time Adaptive Intervention; GPS, Global Positioning System; SD, Standard Deviation

* Corresponding author. University of Kansas, Clinical Child Psychology Program, 2011 Dole Human Development Center, 1000 Sunnyside Ave., Lawrence, KS 66045, USA.
E-mail addresses: Carolina.bejarano@ku.edu (C.M. Bejarano), Christopher.cushing@ku.edu (C.C. Cushing), chriscrick@cs.okstate.edu (C.J. Crick).

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internal states, such as affect, that typically vary within a given day (Cushing, Mitchell, Bejarano, Walters, Crick, & Noser, 2017; Dunton et al., 2014). Indeed, technology provides an innovative opportunity to assess the associations between psychosocial variables and physical activity because many phenotypes that are typically measured through one static assessment are more accurately measured through EMA, in order to examine processes that may fluctuate (Heron et al., 2017). For example, our work has demonstrated that the same constructs can have differential relationships when the independent variable is broken down into between- and within-person components (Bejarano & Cushing, 2018). Additionally, EMA provides a more accurate measurement of variables that are aggregated. For example, innovative technology allows researchers to capture how often an adolescent is outdoors repeatedly or multiple times per day over 20 days which creates a real-time profile. This is innovative over using a retrospective self-reported estimate of time spent outdoors, which is subject to failures of recall and bias.

With regard to internal influences, Dunton et al. (2014); Cushing, Marker, et al. (2017); and Cushing, Mitchell, et al. (2017) report that fluctuations in internal states of affect (i.e., positive and negative) and physical feeling states (i.e., energy and fatigue), are associated with moderate to vigorous physical activity (MVPA) as measured through EMA. Specific to adolescents, the Cushing, Marker, et al. (2017) and Cushing, Mitchell, et al. (2017) team reported that the most important and indeed only significant predictors of MVPA were within-person affect and feeling states. This suggests that not only is it critical to consider both between- and within-person conceptualizations of a variable, but that not doing so could actually lead to conclusions that an effect is between-person when, in fact, no such relationship exists.

External factors such as context appear to play an important role in prompting physical activity. Some findings indicate that prompts to think about contextual factors, such as location and details about one's surroundings, allowed individuals to become aware of additional factors that related to their physical activity, and brought attention to opportunities for physical activity (Li, Dey, & Forlizzi, 2012). Individuals also reported that additional contextual information, such as weather and mood, may have a substantial influence on their physical activity habits (Li et al., 2012). Overall, this existing research communicates the need to study a variety of contextual factors as predictors of health behavior.

As a variety of research has focused on internal predictors of physical activity, this pilot study aims to assess external context on both between- and within-person levels, as predictors of physical activity and psychological states in adolescents. This approach of including affect and feeling states as dependent variables will allow us to expand upon our original findings and work towards a more nuanced understanding of these intricate processes, rather than examining them solely as predictors. As it has not been determined whether such contextual external variables are best measured between or within-person, this pilot represents an innovative application of technology and will examine some of the contextual variables in both ways. For example, adolescents' perception of safety could be important to measure between-person (i.e., how safe one usually feels) and within-person (feeling more or less safe at a given occasion than how one usually feels). Significant associations will provide information about how it will be most beneficial to measure such variables in future studies, and if it is necessary to measure both between- and within-person to fully articulate the impact on physical activity.

2. External context and activity

Research in adolescent samples has compared youth's physical activity at and near home, as well as at and near school, and other locations. Results indicated that the majority of MVPA occurs at school for youth (Klinker, Schipperijn, Christian, Kerr, Ersbøll, Troelsen, 2014) and this effect may be even stronger for adolescents in particular (Carlson et al., 2015; Rainham et al., 2012). Regarding sedentary behavior, research shows that adolescents spend many hours in the evening and weekend watching TV, and this sedentary time is most likely to occur when they are at home (Biddle, Marshall, Gorely, & Cameron, 2009). Additionally, being outdoors has been associated with more MVPA for children and adolescents (Klinker, Schipperijn, Kerr, Ersboll, & Troelson, 2014). For example, 9 to 13-year-old children were found to have higher MVPA when they were outdoors and with friends and family, as measured in an EMA study (Dunton, Liao, Intille, Wolch, & Pentz, 2011). Another study found that neighborhoods with more traffic lights were associated with more walking and cycling for adolescent girls, and living near a cul-de-sac instead of a road was associated with increased MVPA for adolescent boys (Carver, Timperio, & Crawford, 2008). Similarly, the number of roads, traffic density, and amount of crime were negatively associated with physical activity in children 3–18 years old (Davison & Lawson, 2006). Regarding the contextual variable of weather, increases in temperature were associated with more physical activity in adolescents and increases in precipitation were associated with less physical activity (Belanger, Gray-Donald, O-loughlin, Paradis, & Hanley, 2009; Harrison et al., 2017). Together, these findings inform expectations for contextual variables as predictors of MVPA and sedentary behavior in the present study.

3. External context and psychological affect and feeling states

Other work exploring the effects of contextual variables suggests that natural surroundings may have a positive effect on emotions. Past research found that vegetation, such as presence of trees and shrubs in an urban setting, was associated with higher levels of positive affect (Sheets & Manzer, 1991). Additional findings indicate that children 9–13 years old experienced greater enjoyment in outdoor settings as compared to at home or other locations (Dunton et al., 2011) and that there were significant effects of temperature as positively associated with negative affect, while wind and sunlight were negatively associated with negative affect (Denissen, Butalid, Penke, & Van Aken, 2008). Researchers also highlighted the importance of understanding individual differences in how contextual variables influence affect and other outcomes (Denissen et al., 2008). In fact, a subsequent study in adolescents focused on individual variations in affective response to weather, and characterized "weather reactivity types" by distinct profiles (Klimstra et al., 2011). Together, the existing research in adolescents indicates that a variety of questions remain to be explored in order to enhance the current understanding of the intricate relationships among context and affect.

In regard to feeling states, researchers also found that the amount of sunlight was significantly negatively related to tiredness, and acknowledge that this effect is likely related to levels of vitamin D3 and serotonin levels (Denissen et al., 2008). However, there is scarce existing research on the effects of contextual location, vegetation, traffic and safety on subsequent feeling states, such as energy and fatigue.

4. Present study

The present study used an innovative combination of technologically enhanced EMA methodology and sensors to understand the relationships amongst external context and internal affect and feeling states, and external context and physical activity. The purpose of this study is to provide pilot data to inform hypotheses for future studies that will fully examine potential interacting effects of between- and within-person internal and external factors that predict activity. This study aligns with calls for technologically mediated approaches that build toward comprehensive and dynamic models of health behavior processes (e.g., physical activity; Klasnja, Hekler, Korinek, Harlow, & Mishra, 2017; Riley, Cesar, & Rivera, 2014).

The present study aims to develop a preliminary understanding of between-person and within-person associations of context with subjective internal states (i.e., positive affect, negative affect, energy, fatigue) and health behavior (i.e. MVPA, sedentary behavior). We hypothesized that being at school, being outdoors and close to vegetation, and feelings of safety would be associated with more MVPA and less sedentary time. Similarly, we expected that being at home, being around more traffic, and experiencing colder weather and more rain would be associated with less MVPA and more sedentary time. We hypothesized that being outdoors and around more vegetation would be associated with the experience of more positive affect and less negative affect; and that feeling uncomfortable with the weather (e.g., reporting that it is too cold or too rainy) would be associated with more negative affect and less positive affect. We expected that experiencing comfortable temperatures would be related to higher energy and less fatigue. We conducted exploratory analyses of traffic and safety with affect, and of location, vegetation, traffic and safety with feeling states. As noted, the assessment of the contextual predictors as both between- and within-person anticipating that findings will inform future hypotheses are the differential nature of these relationships. Therefore, the between-person vs. within-person expected nature of the effects is not detailed in the hypotheses for the present study.

5. Methods

The full procedures for the present study are described in previous publications (Brannon, Cushing, Crick, & Mitchell, 2016) and are also detailed here as relevant to the specific research questions. All study procedures were approved by the local institutional review board (IRB). We have used the Adapted STROBE Checklist for EMA studies to assist in reporting the methodology used (Liao, Skelton, Dunton, & Bruening, 2016).

5.1. Participants

Adolescents 13 through 18 years old (M age = 15.96, SD = 1.56, 42.3% female) were recruited through the community in a rural Midwestern city. Adolescents were not eligible for the study if they had significant visual impairments or had any physical maladies that limited their physical activity. Thirty eligible participants were recruited and enrolled in the study during the months of August through December. Four of these participants dropped out or provided unusable data. Of the 26 remaining participants, the majority were Caucasian (69.2%; 15.4% American Indian, 11.5% Hispanic, and 3.8% Asian) and upper middle class, according to their reported family income (56% > $60 K; 16% $50 K-$60 K; 20% $30 K-$50 K; 8% $20 K-$30 K).

5.2. Procedures

Recruitment tactics included posting flyers in the community, distributing study information via e-mail, and posting announcements on social media. Following screening, each eligible participant was then scheduled for a baseline visit in-person, at which they provided assent and their parent provided consent to participate in the study.

At the baseline visit, adolescents received an ActiGraph wActi Sleep-BT accelerometer (Actigraph, 2005) and given instructions to wear the accelerometer on their non-dominant wrist throughout the 20-day study period. Research staff explained that the device should be worn continuously and should not need to be taken off or charged. Each participant was also provided an Android smartphone (Google Nexus 4) and instructed in use of the PETE App, which was developed by the third author and calibrated to administer surveys at four times of each study day. At the baseline visit, participants discussed survey timing with the research staff and chose four times to complete 3–5 min surveys on the smartphone each day. Adolescents were required to choose four times at which they would feasibly be available to answer daily surveys, scheduled at least two hours apart (e.g., 7am, 12pm, 4pm, 8pm). Therefore, each participant had their own fixed-interval schedule for EMA prompts. Participants were told they could earn up to $40 as reimbursement for their time, and that this was contingent on completion of the study tasks (Brannon et al., 2016). One 20-day wave of EMA data was collected and 80 prompts were planned to be delivered to each participant (i.e., 4 per day). Therefore, all participants' data included both weekdays and weekend days, and the frequency of weekdays and weekend days varied across participants. These EMA procedures were designed to limit participant burden by allowing adolescents to choose survey times, and the 20-day study period was expected to limit reactivity as compared to a brief EMA period (e.g., 4 days).

5.3. Measures

Objective Measure of Activity. Actilife software v.6.10.2 was used to process the data downloaded after adolescents' participation. Data were binned into 60 s epochs and the sleep and non-wear periods were removed (Troiano et al., 2008). Data were then processed based on Chandler cut points, which is an algorithm that has been established for use of similar methods and age groups (Chandler, Brazendale, Beets, & Mealing, 2016). The specific cut points used for the present study were: sedentary (0–3660), light activity (3661–9804), and MVPA (9805 and above). The variables of MVPA and sedentary time were calculated by totaling the number of minutes of each in the 30-min interval following each EMA survey administration.

Table 1
Ecological momentary assessment (EMA) items, response options, and descriptive statistics for context variables.

Construct	EMA Survey question	Response Options				
		1	2	3	4	5
Context: Location	Where are you right now?	Home (61.3%)	School (17.3%)	Car/Van/Truck (12.4%)	Outdoors (6.2%)	At the store (2.7%)
Context: Vegetation	How many TREES AND PLANTS are there in the area where you are right now?	No trees and plants (21.3%)	– (17.8%)	Some trees and plants (34.1%)	– (10.8%)	A lot of trees and plants (16.1%)
Context: Traffic	How much TRAFFIC is on the closest street to where you are right now?	No traffic (50.6%)	– (20.2%)	A little traffic (17.7%)	– (6.1%)	A lot of traffic (5.4%)
Context: Safety	How SAFE do you feel right now?	Unsafe (5.5%)	– (4.6%)	Somewhat safe (16.4%)	– (19.6%)	Very safe (53.9%)
Context: Weather	What is the WEATHER like outside?	Too hot (24.1%)	Too cold (25.1%)	Just right (44.2%)	Too rainy (5.2%)	Too windy (1.4%)

Note. The EMA questions were part of a survey administered via smartphone four times daily over 20 study days. Response options for Location and Weather were coded categorically. Response options for Vegetation, Traffic, and Safety items were treated as continuous. Percent of each response are presented for the five context variables out of number of valid responses; Location: 1,900, Vegetation: 1,882, Traffic: 1,878, Safety: 1,875, Weather: 1873.

Table 2
Descriptive statistics for affect, feeling state, MVPA, and sedentary dependent variables.

Variable	Mean (SD)	Proportion rated 0 (%)
Positive Affect	12.66 (4.77)	10.0
Negative Affect	7.59 (3.71)	45.4
Fatigue	6.20 (3.11)	28.8
Energy	6.58 (3.10)	22.8
MVPA	1.20 (2.95)	65.2
Sedentary	20.35 (7.37)	.4

Note. SD = standard deviation. MVPA = Moderate to Vigorous Physical Activity. The column "Proportion rated 0" indicates the percent of responses on which participants responded "1: Not at all" or engaged in 0 min of MVPA or sedentary time. MVPA and Sedentary refer to minutes participants engaged in each, during the 30 min after daily surveys.

Context Questions. Five EMA items were used to obtain information about participants' location, proximity to vegetation, amount of nearby traffic, feelings of safety in their current environment, and current weather. The specific questions and response options are included in Table 1. Participants answered these questions with a 5-point Likert scale in each survey administration (i.e., 4 times each day for 20 days).

Positive and Negative Affect Questions. Five items were used to measure adolescents' positive and negative affect, respectively, and rated on a 5 point Likert scale from *1: Not at all* to *5: Extremely*. Participants were asked to report on the extent they experienced positive and negative affect at the time of each of the four daily survey administrations. Items were obtained from the short form of the Positive and Negative Affect Schedule (I-PANAS-SF; Thompson, 2007). Both the positive and negative affect subscales in the current sample had good internal consistency, with α = 0.83 for positive and α = 0.82 for negative. Items assessing positive and negative affect were presented in alternating order.

Energy and Fatigue Questions. Six items were used to measure adolescents' physical feeling states, also on a Likert scale at the four times of each study day. The items were chosen from the Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1971). Three items with the highest factor loadings from the "Vigor-Activity" subscale (i.e., *energetic, full of pep, vigorous*) were used to measure energy. Three items with the highest factor loadings were also chosen from the "Fatigue-Inertia" subscale of the POMS to measure fatigue (i.e., *fatigued, exhausted, worn out*). Both subscales had good internal consistency, with α = .84 for energy and α = 0.88 for fatigue. Participants were asked to report the extent to which they felt each feeling state in the time since the previous survey.

5.4. Data analysis

We used SPSS statistics (Version 22) to determine descriptive statistics for all study variables, then used SAS PROC MIXED (Version 9.4) to run a series of multilevel models. Person-mean centering was used to calculate between-person and within-person variability of the time-varying predictors, proximity to vegetation, amount of nearby traffic, and feelings of safety in the environment. The location and weather predictors were not calculated as between and within person variables, but were coded categorically, as deviation from being at *home* location or experiencing *just right* weather. Once models for time were established, separate models were run for each context variable predicting the four dependent variables.

5.5. Power

A post-hoc power analysis was conducted using Optimal Design Plus software for repeated measures with clusters of 26. Results indicated that for the Level 2 ICC of 0.081 for physical activity, the observed power was .18. For the Level 1 ICC of 0.919 for physical activity, the observed power was .90. The calculations indicated that 175 participants would be needed to rise above 0.80 power for Level 2.

6. Results

6.1. Preliminary analyses and models for time

Participants provided data that indicated high compliance with the study protocol. Data were screened for invalid responding using a mixture modeling procedure described elsewhere (Cushing, Marker, Bejarano, Crick, & Huffhines, 2017). Overall, participants completed 87.5% of EMA surveys and provided valid accelerometer data on 75.4% of the study days. There were both valid EMA data and accelerometer data for 58.4% of the occasions. There was not a significant effect of time on rate of survey completion. Descriptive statistics for the main study variables are included in Tables 1 and 2. The model for time predicting positive affect, negative affect, energy, and fatigue were each random linear, meaning the addition of a random linear effect of time significantly improved model fit for each of these dependent variables, based on −2 Restricted Log Likelihood (-2LL). The dependent variables of MVPA and sedentary time had no fixed or random effects of time; the empty model fit best for both of these variables.

6.2. Associations with dependent variables

MVPA. Weather was significantly associated with MVPA in the 30 min after EMA surveys. In particular, reporting that it was *just right* ($\beta = 0.45$, $p < .05$) was positively related to subsequent MVPA, while reporting that it was *too rainy* ($\beta = -0.91$, $p < .05$) was negatively related.

Sedentary Behavior. Location was significantly related to sedentary behavior, in that being at home ($\beta = 2.18$, $p < .0001$) was positively related to subsequent sedentary behavior, while being at school ($\beta = -1.54$, $p < .01$) or outdoors ($\beta = -5.60$, $p < .0001$) was negatively associated. Weather was also associated with sedentary behavior. Specifically, reporting that the weather was *just right* ($\beta = -1.109$, $p < .05$) was negatively associated with sedentary behavior, while *too rainy* ($\beta = 2.32$, $p < .05$) was positively related.

Positive Affect. Location was significantly associated with positive affect such that being at home ($\beta = -1.47$, $p < .0001$) was negatively related to positive affect, while being at school ($\beta = 1.19$, $p < .0001$), in the car ($\beta = 0.77$, $p < .01$), or outdoors ($\beta = 1.66$, $p < .0001$) were positively associated with positive affect. Within-person vegetation (i.e., being around more trees and plants than an individual typically reports) was also significantly related, such that being in proximity to more vegetation was associated with higher positive affect ($\beta = 0.21$, $p < .01$). Within-person traffic (i.e., being around more traffic than an individual typically reports) was also significantly related, such that being in proximity to more traffic was associated with higher positive affect ($\beta = 0.43$, $p < .001$). Last, weather was significantly associated with positive affect. Reporting that it was *just right* ($\beta = 0.66$, $p < .001$) was positively related to positive affect, while being *too hot* ($\beta = -0.80$, $p < .01$) and *too cold* ($\beta = -0.53$, $p < .05$) were negatively related.

Negative Affect. Location was significantly related to negative affect; specifically, being at home was negatively related to negative affect ($\beta = -0.31$, $p < .05$), and being in the car was positively related to negative affect, ($\beta = 0.57$, $p < .01$). Within-person traffic, or being around more traffic than usual, was positively associated with negative affect, ($\beta = 0.12$, $p < .05$). Both between-person and within-person safety were significantly related to negative affect, such that feeling more safe than peers ($\beta = 2.34$, $p < .001$) and feeling more safe than one typically reports ($\beta = 0.49$, $p < .0001$) were positively associated with it. Last, weather was related to negative affect, in that it being *too* *rainy* outside was positively related to negative affect ($\beta = 1.14$, $p < .0001$).

Energy. Location was significantly associated with energy, in that being at home was negatively related to reported energy levels ($\beta = -0.73, p < .0001$), while being at school ($\beta = 0.36, p < .05$), in the car ($\beta = 0.40$, $p < .05$), or outdoors ($\beta = 1.05$, $p < .0001$), were positively related to feeling energetic. Within-person vegetation was also significantly related to energy, such that being in proximity to more vegetation than usual was associated with higher energy ($\beta = 0.19$, $p < .001$). Within-person traffic was also positively associated with energy; being in proximity to more traffic was related to higher energy ($\beta = 0.27$, $p < .0001$). Furthermore, weather was significantly associated with energy. Specifically, reporting that the weather was *just right* ($\beta = 0.35$, $p < .01$) was positively related to energy, while reporting that it was *too cold* ($\beta = -0.40$, $p < .05$) was negatively related.

Fatigue. Location was significantly related to fatigue; being outdoors was negatively related to fatigue ($\beta = -0.53$, $p < .05$). Lastly, weather was significantly related to fatigue, such that reporting the weather was *just right* was negatively related to fatigue ($\beta = -0.33$, $p < .05$).

7. Discussion

The fit between our hypotheses and results was mixed, but provided some insight regarding contextual predictors as measured both between- and within-person. The significant associations of weather with activity, as well as the expected associations that did not emerge, suggest that rainy conditions inhibit tendencies toward physical activity more than conditions of temperature extremes, which fits with previous findings (Harrison et al., 2017). It is possible that going outside for activity is less feasible when it is rainy, and still an option when it is very hot or very cold. The findings pertaining to sedentary behavior fit with hypotheses and suggest that adolescents may be more likely to engage in sedentary behaviors at home, such as homework or watching television (Biddle et al., 2009; Gorely, Marshall, Biddle, & Cameron, 2007); however, when outside of the home they may be less likely to be sitting, but not necessarily engaging in physical activity.

The associations of weather with affect fit with hypotheses; however, our study did result in some unhypothesized findings for context as a predictor of affect. Particularly, the findings that being at home (i.e., location) was negatively associated with both positive and negative affect and that being in the car and around more traffic than usual was positively related to both positive and negative affect merit further interpretation. It is important to note that previous studies have demonstrated that children experience higher negative affect when they are with their family relative to their friends (Dunton et al., 2011). Our findings may fit with this notion, as the situations of being at home and in the car, and therefore around more traffic, may also be situations when adolescents tend to be around family members rather than friends. However, it could be that for some adolescents, these are contexts that elicit positive affect while for others they elicit negative affect. Consequentially, our study may not be well equipped to fully understand the effect of location, as it may interact with important social factors to confer the final effect on affect. Moreover, the findings of within-person traffic as a significant predictor, but not between-person traffic, provides some confirmation that it is necessary to measure contextual predictors as time-varying when possible. Lastly, safety was the only contextual variable for which both between- and within-person predictors yielded significant associations with a dependent variable (i.e., negative affect), which may suggest that this represents a different process when examined across adolescents as compared to one adolescent's intraindividual process.

Findings with feeling states as dependent variables also provided insight towards the differentiation between within-person and between-person effects, as being around more vegetation and traffic than usual (i.e., within-person variables) were associated with more energy but the same effects did not emerge for the between-person predictors. We speculate that being around more traffic and vegetation occurs outside of the home, and fits with the findings pertaining to location and feeling states and the notion that social factors may also influence these relationships. However, these findings are results of exploratory analyses, and therefore may only provide preliminary information about such effects.

7.1. Limitations

It is important to consider the limitations of the present study in evaluating the findings and their generalizability. First of all, the homogeneity of the sample as predominantly Caucasian and middle-class may limit generalizability of findings to demographically diverse adolescents. This homogeneity may also have affected assessment of contextual variables, such as safety. It is possible that the average SES of the adolescents in the sample represents those that would generally live in safe environments; therefore, findings may differ if examined in a sample with more diversity in SES, or in a different city. In addition, specific times of day or days of the week may be associated with likelihood to engage in physical activity or sedentary behavior. In fact, existing evidence suggests that adolescents' health behaviors are location-specific and that locations may vary by the time of day or day of the week (Wiehe et al., 2008). Similarly, boys are known to be more physically active than girls. Both of these factors are appropriate for inclusion as substantive hypotheses in larger more fully-powered investigations. Though our EMA data collection provided many observations, the small sample size at the person level is a limitation, as it was not adequately powered to examine moderation effects. However, it is noted that there is substantial evidence regarding environmental influences on physical activity at Level 2 (Biddle et al., 2009; Carver et al., 2008; Klinker, Schipperijn, Christian et al., 2014; Klinker, Schipperijn, Kerr et al., 2014) Therefore, the present study focused on Level 1 influences on physical activity to begin to provide information about an individual in a varying environmental context. Approximately 175 participants would be needed for appropriate power in answering the substantive questions at Level 2 (between-person). Therefore, further investigation of how external and internal factors, on both between and within person levels, may interact to predict MVPA or sedentary behavior, will need to be conducted in larger studies in the future.

While a 20-day wave of data collection may have been useful in reducing reactivity to smartphone surveys or to wearing an activity monitor, these methods still hold potential for bias and are noted as a limitation. Moreover, the inconsistency of weekdays vs. weekend days and times of surveys across participants is a factor that likely improved data acquisition, but is also noted as a limitation.

7.2. Implications and future direction

The findings focused on activity show that adolescents may be less likely to engage in MVPA when weather conditions are not ideal in their opinion, and more likely to be active and less sedentary when weather conditions are ideal. Therefore, interventions that prompt activity during optimal weather conditions could be helpful in promoting adolescent physical activity. Our findings suggest that being at home is a key location where adolescents may need to break habits of predominantly sedentary activities, and that interventions that prompt activity once they are outside of the home may be effective in moving from *not sedentary* to *active.*

Overall, our findings suggest that the contextual variables of location, weather, traffic, safety, and vegetation could be important to include in future models of health behavior in the adolescent age group. Generally, it appears the weather and location may be the factors that are most consistently related to activity and psychological states, which fits with previous findings in this area (Bélanger et al., 2009; Li et al., 2012). Moreover, the findings provide preliminary evidence that it may be more accurate and informative to measure these contextual variables through ecological momentary assessment as compared to other methodology, and that evaluating them as between- and within-person when appropriate may allow for a more detailed understanding. These findings improve on the current literature and plans for future work in JITAIs (Nahum-Shani et al., 2016) in that they propose the importance of contextual variables that may provide effective intervention points. The use of EMA to obtain these pilot data was valuable, as it allowed us to gather information about changing contextual variables and how they relate to fluctuating activity and psychological states, which otherwise would not have been as nuanced. However, this study serves as a preliminary step, as much remains to be known about the relationships among context, affect, feeling states, and activity.

Recent advances in methodology for geographically-explicit ecological momentary assessment (GEMA) will be valuable for continued study of factors influencing mental health and well-being. Research in many domains is moving forward with establishing standardized methodology with use of mobile devices (Kirchner & Shiffman, 2016) as mobile health interventions have proven effective in changing health behavior particularly for youth (Fedele, Cushing, Fritz, Amaro, & Ortega, 2017). Current technology offers the potential to track context variables of this nature, such as through geolocation and GPS (Global Positioning System) on mobile devices, and researchers have begun to harness this potential in relation to health behavior.

Future work to build JITAIs will determine how relationships amongst contextual and psychosocial predictors and health behavior outcomes may differ for each individual, and adapt interventions to utilize intervention points that will be most beneficial to the specific adolescent (Noser, Cushing, McGrady, Amaro, & Huffhines, 2017). Though findings from our pilot study serve as a preliminary step, continuing work of this nature will move the field forward in advancing methodology to study individual differences in health behavior, which may then inform real-time interventions.

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