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Editor's Choice: Dual-process model of older adults' sedentary behavior: an ecological momentary assessment study

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Abstract

Objective: A 10-day ecological momentary assessment (EMA) study was conducted to test a dual-process model of older adults' sedentary behavior.

Design: Older adults ($n = 104$, 60–98 years) answered 6 EMA questionnaires/day to assess conscious processes (i.e. momentary intentions, self-efficacy to limit sedentary behavior over the next two hours) and wore an activPAL accelerometer to measure sedentary behavior. Habit strength for sedentary behavior, a non-conscious process, was self-reported at an introductory session.

Main outcome measure: Time spent sitting in the two hours after the EMA prompt.

Results: Older adults engaged in less sedentary behavior on occasions when their intentions ($b = -1.63$, $p = 0.02$) and self-efficacy ($b = -2.01$, $p = 0.003$) to limit sedentary behavior were stronger than one's average level of intentions or self-efficacy, respectively; however, older adults' average level of intentions ($b = -5.30$, $p = 0.05$) or self-efficacy ($b = 2.77$, $p = 0.27$) to limit sedentary behavior were not associated with sedentary behavior. Older adults with stronger sedentary behavior habits engaged in greater sedentary behavior in the two hours following the EMA prompt ($b = 2.04$, $p = 0.006$).

Conclusion: Sedentary behavior is regulated by conscious and non-conscious processes. Interventions targeting older adults' sedentary behavior should promote momentary intention formation and self-efficacy beliefs to limit sitting as well as content to disrupt habitual sedentary behavior.

Keywords

Habits; intentions; self-efficacy; intensive longitudinal data; sitting

Estimates suggest that the majority of older adults, or adults age 60þ years, sit for more than half of their waking hours – a level of behavior that equates to more than 9 waking hours per day (Harvey, Chastin, & Skelton, 2015; Matthews et al., 2008). Although sedentary behavior

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is a natural part of one's daily activities, engaging in excessive levels of sedentary behavior (i.e. ≥8 waking hours per day) is associated with a variety of negative health consequences among older adults including increased risk of premature death, chronic conditions such as metabolic syndrome and obesity, as well as decrements in geriatric-related outcomes such as physical and cognitive functioning and quality of life (Copeland et al., 2017; de Rezende, Rey-López, Matsudo, & Luiz, 2014; Keadle, Arem, Moore, Sampson, & Matthews, 2015). Given the prevalence of sedentary behavior (commonly referred to as time spent sitting) as well as the negative health consequences associated with excessive sedentary behavior, a growing number of studies have been devoted to better understand the motivational processes regulating sedentary behavior (e.g. Brug & Chinapaw, 2015; Chastin et al., 2015; Greenwood-Hickman, Renz, & Rosenberg, 2016). This study extends previous research by using a dual process framework and ecological momentary assessment (EMA) methods to identify the motivational processes underlying older adults' sedentary behavior within the context of everyday life.

Dual process models of sedentary behavior

Contemporary health behavior theories such as the theory of planned behavior (Ajzen, 1991), social cognitive theory (Bandura, 1977) or transtheoretical model (Prochaska & Marcus, 1994) have been widely employed to explain, predict and even intervene on various health behaviors. A common feature of these theories is the reliance on the idea that human behavior is driven by rationality. Therefore, *conscious processes* such as goals, beliefs and attitudes towards health behaviors drive subsequent engagement in those behaviors according to the aforementioned theories. Yet, humans do not always behave in rational ways (e.g. Sheeran, Harris, & Epton, 2014; Webb & Sheeran, 2006). In fact, there is strong evidence that health behaviors while, in part, are explained by these theories, conscious processes only explain a small proportion of variance in these health behaviors (e.g. McEachan, Conner, Taylor, & Lawton, 2011; Rhodes & Dickau, 2013; Webb & Sheeran, 2006). More recent evidence suggests that *non-conscious processes*, which represent pre-existing automatic associations spontaneously activated by contextual cues encountered within one's environment, play an important role in regulating behavior (Bargh & Ferguson, 2000; Evans, 2008; Hofmann, Friese, & Wiers, 2008; Strack & Deutsch, 2004). For example, habits, which represent an example of a non-conscious process, develop over time through the repeated pairing of a contextual cue in the environment with a behavioral response so that over time encountering that cue automatically elicits an impulse to engage in the behavior (Aarts & Dijksterhuis, 2000; Aarts, Paulussen, & Schaalma, 1997). Habits may be particularly powerful predictors of older adults' sedentary behavior given the amount of time older adults have had to develop cue-behavior linkages within their environment (Aarts et al., 1997; Verplanken, Walker, Davis, & Jurasek, 2008).

Dual process models acknowledge the roles that both conscious and non-conscious processes play in regulating individual behavior. Indeed, accumulating evidence indicates that a dual process framework is likely useful for explaining health behaviors like sedentary behavior (Hagger, 2016; Sheeran, Gollwitzer, & Bargh, 2013). Although the majority of work investigating the motivational processes underlying sedentary behavior has focused exclusively on conscious processes (e.g. Chastin et al., 2015; Greenwood-Hickman et al., 2016), a small number of studies have approached understanding sedentary behavior from a dual process perspective (e.g. Conroy, Maher, Elavsky, Hyde, & Doerksen, 2013; Maher & Conroy, 2016). For instance, in a daily diary study of college students, Conroy et al. (2013) found that daily intentions and self-efficacy to limit sedentary behavior (i.e. conscious processes) as well as sedentary behavior habit strength (i.e. a non-conscious process) were associated (at both the between- and within-person level) with daily sedentary behavior. Maher and Conroy (2016) extended this dual-process, daily diary approach to understanding older adults' sedentary behavior and found that daily intentions, self-efficacy and plans to limit sedentary behavior as well as habits for sedentary behavior all contributed to daily sedentary behavior.

Within-person dynamics of sedentary behavior

In addition to establishing that both conscious and non-conscious processes play a role in regulating sedentary behavior, these daily diary studies also captured natural daily variation in sedentary behavior and the conscious processes regulating sedentary behavior (Conroy et al., 2013; Maher & Conroy, 2016). Capturing such variation is important because it allows for the differentiation of between-person processes (i.e. differentiation between more or less sedentary people overall) from within-person processes (i.e. differentiation between occasions during which people engage in or less sedentary behavior that is typical for them) (e.g. Nesselroade & Ram, 2004). For instance, Maher et al. (2016) found that it was the strength of older adults' plans to limit sedentary behavior on a given day (i.e. within-person) as opposed to older adults usual or average strength of plans (i.e. between-person) that predicted daily sedentary behavior. As this finding suggests, disaggregating between- and within-person processes may provide meaningful information in the prediction and modeling of sedentary behavior.

Despite the aforementioned strengths of previous research (e.g., Conroy et al., 2013; Maher and Conroy, 2016), this work is limited because the time scale by which motivation and behavior were assessed (i.e. day-level) is different than the time scale in which sedentary behavior actually occurs (Scholz, 2019). Sedentary behavior is a repeat-occurrence health behavior in that it occurs regularly, often multiple times per day, with the duration of sedentary behavior varying considerably from moment to moment (Dunton, 2017). Therefore, to capture the motivational processes regulating sedentary behavior at a given moment, intensive data collection methods assessing the phenomenon of interest as it occurs must be employed (Dunton, 2017, 2018). Additionally, assessing behavior and the motivational processes regulating behavior at the momentary-level can have implications for the development of just-in-time adaptive interventions designed to deliver the most effective and appropriate intervention content given the person and their current context.

EMA is a real-time data capture strategy in which participants are repeatedly and intensively assessed on constructs such as one's current behaviors, cognitions, or affective states in the context of everyday life (Stone & Shiffman, 1994). Additionally, EMA responses are time-stamped to facilitate the pairing of EMA data with other passive, sensor data such as accelerometers. Therefore, EMA methods combined with accelerometers are well-positioned to study the dual processes regulating sedentary behavior at a given moment

(Dunton, 2017, 2018). To the authors' knowledge, no such study has used EMA to investigate conscious and non-conscious motivational processes underlying older adults' sedentary behavior to date.

The present study

A 10-day EMA study with passive, sensor-based monitoring was conducted to test a dual-process model of older adults' sedentary behavior. Intentions and self-efficacy were chosen as conscious processes of interest given the prominent role these constructs play within contemporary theories of health behavior change such as the theory of planned behavior and social cognitive theory (Ajzen, 1991; Bandura, 1977) as well as previous evidence documenting within-person fluctuations in these motivational constructs and co-variation of within-person fluctuations in these motivational constructs and subsequent activity-related behavior (e.g. Conroy, Elavsky, Hyde, & Doerksen, 2011; Conroy et al., 2013; Maher & Dunton, 2019; Pickering et al., 2016). Sedentary behavior habit strength was a non-conscious process of interest given previous evidence that sedentary behavior habit strength was associated with daily behavior even after controlling for conscious processes (Conroy et al., 2013; Maher & Conroy, 2016). Such work also formed the basis for hypothesized associations in the present study. Specifically, sedentary behavior (i.e. time spent sitting in the two hours after the EMA prompt) was hypothesized to be (a) negatively associated with intentions and self-efficacy to limit sedentary behavior at the between- and within-person level, and (b) positively associated with sedentary behavior habit strength at the between-person level. These hypothesized associations will control for each other in the same model. Thus, significant associations would represent independent effects. In testing these hypotheses, covariates were controlled for at the between- and within-person level, including day-of-week and time-of-day (within-person covariates) and, sex, age, employment status, body mass index, and physical functioning (between-person covariates). Additionally, physical activity was included as a covariate at both a between-person (i.e. one's average level of physical activity in the two hours after the EMA prompt across all occasions) and within-person (i.e. occasion-level deviation from one's average level of physical activity in the two hours after the EMA prompt) level. Physical activity was controlled for at the between- and within-person level to account for potential confounding that may be due to behavioral displacement.

Methods

Participants

Participants of Project ABLE (Adults' Behaviors in Living Environments) were community-dwelling older adults residing in Los Angeles County (Maher, Rebar, & Dunton, 2018). Study recruitment was conducted through announcements at local senior centers, retirement communities, and a subject pool of older adults that had previously participated in research studies at a university in Los Angeles County. Older adults were included if they were age 60 years or older and living in Los Angeles County. Age 60 years or older was chosen as the age cut off for older adults to align with socially constructed definitions of old age which suggest age 60 or 65 years, roughly equivalent to retirement ages in most developed countries, as the beginning of old age (Gorman, Randel, German, & Ewing, 1999) as well as to align with epidemiologic data examining sedentary behavior levels that typically considers adults age 60 and over to represent older adults (e.g. Evenson, Morland, Wen, & Scanlin, 2014; Harvey et al., 2015). Individuals were excluded from participation if they did not speak and read English fluently, had any functional limitations that prevented standing or walking on their own or utilizing a smartphone's basic functions, or were diagnosed by a physician as having dementia or Alzheimer's Disease.

Procedures

In total, this study lasted 10 days. On Day 1, participants attended an introductory session where they were familiarized with the study procedures and the equipment to be used in the study. The two main pieces of study equipment were a MotoG4 smartphone and an ActivPAL3 micro activity monitor. Participants were assigned a MotoG4 smartphone and trained on how to use the smartphone to answer brief electronic questionnaires randomly occurring six times per day between the hours of 8:00 am and 8:00 pm. These brief electronic questions were delivered through the EMA smartphone application for Android operating systems, MovisensXS. Each time an electronic questionnaire was to be completed, the smartphone emitted an auditory signal and vibration alerting the participant that a questionnaire was to be completed. Upon hearing the auditory signal and/or feeling the vibration, participants were instructed to stop their current activity and complete the electronic questionnaire. EMA items assessed participants' current behavior, context, motivation, affective and physical feeling states. Each electronic questionnaire took approximately 2–3 min to complete. If a participant did not begin the electronic questionnaire within five minutes of the initial auditory signal, the participant received a reminder auditory signal. Participants received 3 reminder auditory signals before the questionnaire became inaccessible.

Also at the introductory session, participants were trained on how to wear the ActivPAL3 micro activity monitor. Participants were instructed to wear the monitor on their anterior thigh during all sleeping and waking hours during the 10-day study. Activity monitors were waterproofed using a nitrile sleeve and athletic tape to allow the monitor to be worn while showering; however, participants were instructed to remove the monitor if it were to be submerged under water such as during a bath or swimming. Participants were asked to record any times when they were not wearing the activity monitor on an activity monitor log. Participants also recorded their sleep and wake times each day while in the study to allow the research team to correctly categorize sedentary behavior as activities completed in a seated or reclined position while awake.

Prior to leaving the introductory session, participants completed a paper and pencil questionnaire to provide demographic information. Upon leaving the introductory session, participants began receiving EMA prompts and the activity monitor began recording data. Depending on the time of day that the participant left the introductory session, they may not have received the full 6 EMA questionnaires on Day 1; however, all available, valid data from Day 1 was included in the analysis. During the study, participants received one phone call or email from the research staff to inquire about any issues related to the study equipment and to remind participants of the study procedures. All study procedures were approved by the local Institutional Review Board.

Measures

Sedentary behavior—Sedentary behavior was assessed using the ActivPAL3 micro activity monitor. This device has been shown to be a valid and reliable measure of posture (e.g. sitting, standing) and movement (e.g. walking) in older adults (Grant, Dall, Mitchell, & Granat, 2008; Grant, Ryan, Tigbe, & Granat, 2006). Activity monitor data were collected in 15-second epochs and proprietary algorithms are then used to calculate time spent sitting, standing and stepping within those epochs. Activity monitor data were time-stamped to facilitate linking with time-stamped EMA data. Only activity monitor data in the 120 min after each EMA prompt were included in this study to correspond with the time frame specified within the intention and self-efficacy EMA items. Therefore, sedentary behavior was operationalized as time spent sitting in the 120 min after the EMA prompt. Activity monitor logs were used to screen for participant non-wear during the 120 min after the EMA prompt. Following missing data procedures in other physical activity EMA studies (Maher, Dzubur, Huh, Intille, & Dunton, 2016; Maher et al., 2017), sedentary behavior data were considered valid if participants indicated they wore the activity monitor for at least half of the 120-min period after the EMA prompt.

Intentions—Intentions to limit sedentary behavior were assessed as part of the EMA protocol using a single-item adapted from previous research (Maher & Conroy, 2016; Pickering et al., 2016). Participants indicated the extent to which they agreed with the statement, ‘Over the next two hours, I intend to limit the time I spend sitting to less than an hour and a half’. Response options ranged from 1 (*Strongly disagree*) to 5 (*Strongly agree*).

Self-efficacy—Self-efficacy to limit sedentary behavior was assessed as part of the EMA protocol using a single-item adapted from previous research (Maher & Conroy, 2016; Pickering et al., 2016). Using a scale ranging from 1 (*Strongly disagree*) to 5 (*Strongly agree*), participants indicated the extent to which they agreed with the statement, ‘Over the next two hours, I believe that I can limit the time I spend sitting to less than an hour and a half’.

Habit strength—Sedentary behavior habit strength was assessed through questionnaire at the introductory session using the 4-item Self-Report Behavioural Automaticity Index (Gardner, Abraham, Lally, & de Bruijn, 2012), a subscale of the Self-Report Habit Index (Verplanken & Orbell, 2003). Participants rated items (e.g. ‘Sitting for extended periods of time is something I start doing before I realize I am doing it’) on a scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). Responses to the 4-item scale were internally consistent ($\alpha = 0.90$); therefore, responses were averaged to create a composite habit score.

Physical activity—Physical activity was assessed using the ActivPAL3 micro activity monitor. Given that walking is the most common form of physical activity for older adults, physical activity was operationalized as time spent stepping in the 120 min after the EMA prompt. Time spent stepping was determined by ActivPAL’s proprietary algorithms. The

ActivPAL activity monitor is a valid and reliable measure of older adults' walking behavior (Grant et al., 2006, 2008).

Demographics—Participants self-reported their sex, age, employment status, physical functioning, and height and weight at the introductory session. Participants categorized their current employment status as working full time, working part time, retired, or unemployed. Older adults also completed the Later Life Function and Disability Instrument II (Haley et al., 2002) to assess physical functioning. Higher scores on this measure indicated greater physical functioning. Body mass index was calculated from participants' self-reported height and weight ($BMI = kg/m^2$).

Temporal processes—EMA data were time-stamped to created variables to account for day of week and time of day variables. Day of week data was coded into a dichotomous variable of weekday (reference group) or weekend day. For time of day, EMA prompts occurring from 8:00 am to 11:59 am were coded as morning (reference group), from 12:00 pm to 3:59 pm as afternoon, and from 4:00 pm to 8:00 pm as evening.

Data analysis

Data preparation: Time-varying predictor variables assessed through EMA (i.e. intentions and self-efficacy) and accelerometers (i.e. physical activity) were disaggregated to create between-person and within-person versions of each variable. The between-person version is grand mean-centered to represent the deviation of that older adult from the group mean whereas the within-subject version is person mean-centered to represent a deviation of a given observation from that older adult's own mean (Enders & Tofighi, 2007). Therefore, within-person results occurring at the prompt level can be interpreted as adjusted for between-person effects. Between-person and within-person variables were created using the *xtcenter* procedure (Dzubur, 2015) in STATA Version 14.2. Sedentary behavior habit strength, age, BMI, and physical functioning were grand mean-centered. Sex was dummy-coded with males being the reference category. Employment status was dummy coded with participants indicating working at all (i.e. full time or part time) code as 1 and participants not working (i.e. retired or unemployed) coded as the reference category.

Multilevel models: A linear multilevel model was used to test the study objective. Multilevel models adjust standard errors of parameter estimates to account for the clustering of observations within people (Snijders & Bosker, 1999). Multilevel models were tested using *mixed* procedure in STATA Version 14.2. The linear multilevel model used to predict sedentary behavior in the two hours following the EMA prompt is outlined by Equations (1)–(4):

$$\begin{aligned}\text{Level}-1\text{: Sedentary Behavior}_{di} &= \beta_{0i} + \beta_{1i}(\text{Within} - \text{Person Intentions}_{di}) \\ &+ \beta_{2i}(\text{Within} - \text{Person Self} - \text{Efficacy}_{di}) \\ &+ \beta_{3i}(\text{Within} - \text{Person Physical Activity}_{di}) \\ &+ \beta_{4i}(\text{Day of Week}_{di}) + \beta_{5i}(\text{Time of Day}_{di}) + e_{di}\end{aligned} \tag{1}$$

$$\begin{aligned}\text{Level}-2\text{: }\beta_{0i} = \gamma_{00} + \gamma_{01}(\text{Between} - \text{Person Intentions}_i) \\ + \gamma_{02}(\text{Between} - \text{Person Self} - \text{Efficacy}_i) + \gamma_{03}(\text{Habit Strength}_i) \\ + \gamma_{04}(\text{Between} - \text{Person Physical Activity}_i) + \gamma_{05}(\text{Sex}_i) + \gamma_{06}(\text{Age}_i) \\ + \gamma_{07}(\text{BMI}_i) + \gamma_{08}(\text{Employment Status}_i) + \gamma_{09}(\text{Physical Function}_i) + u_{0i}\end{aligned} \quad (2)$$

$$\beta_{(1-2)i} = \gamma_{(1-2)0} + u_{(1-2)i} \quad (3)$$

$$\beta_{(3-5)i} = \gamma_{(3-5)0} \quad (4)$$

where γ_{00} is the expected level of sedentary behavior in the two hours following the EMA prompt for a male, not working, and of average age, BMI, and physical functioning in the sample, γ_{01} and γ_{02} indicates the between-person associations between intentions and self-efficacy and sedentary behavior, respectively, and γ_{03} represents the association between sedentary behavior habit strength and sedentary behavior. In turn, γ_{10} and γ_{20} indicate the strength of the within-person association between intentions and self-efficacy and sedentary behavior, respectively. Time-varying covariates controlling for within-person physical activity, day of week, and time of day are represented by γ_{30} to γ_{50} and time-invariant covariates controlling for between-person physical activity and demographic characteristics including sex, age, BMI, employment status, and physical functioning are captured by γ_{04} to γ_{09}. Unexplained between-person differences in levels of sedentary behavior are captured by u_{0i} and unexplained differences in the within-person association between intentions and self-efficacy and sedentary behavior are captured by u_{1i} and u_{2i}, respectively.

Results

Data availability

One hundred and four older adults enrolled in the study and completed the study procedures. Of the programmed 6240 EMA questionnaires (60 surveys across 104 participants), 209 EMA surveys were not delivered because the EMA questionnaire was to be delivered before the participant attended their introductory session on Day 1. This resulted in a possible 6031 EMA observations among participants; however, 6 EMA prompts were not delivered for unknown technical reasons. Of the 6025 delivered EMA prompts, 42 observations were excluded because accelerometer wear was not considered valid in the two hours after the EMA prompt. This was determined by consulting non-wear times indicated by participants' in their activity monitor logs. Any occasion where participants self-reported not wearing the activity monitor for 60 min or more in the 120 min after an EMA prompt was considered not valid. An additional 473 occasions were excluded due to missing EMA data on intentions and self-efficacy. Additionally, all answered EMA observations ($n = 45$) from one participant were excluded because they did not provide demographic information on self-reported height and weight (necessary to calculate BMI) and employment status. This resulted in a final analytic sample of 5465 answered EMA prompts with valid accelerometer data across 103 participants (91% compliance across all occasions considering the possible 6031 observations). Of participants included in the analytic sample, the average participant provided 53 EMA observations across the 10-day study (Range = 11–60). Across the entire sample, missing data were more likely to occur among female participants (90% compliance rate) compared to male participants (95% compliance rate; OR = 2.16, $p < 0.01$) and on weekend days (90% compliance rate) compared to weekdays (93% compliance rate; OR = 1.55, $p < 0.01$). Rates of missingness did not differ by age, BMI, ethnicity, or time of day. Moreover, missing an EMA prompt was not related to the amount of sedentary behavior accumulated in the 2 h after an EMA prompt ($b = 0.92$, $p = .49$). Further details on compliance with study procedures can be found elsewhere (Maher et al., 2018).

Participant characteristics

The mean age of the participants included in the analytic sample was 72 years (SD = 7 years, Median = 71 years, Range: 60–98 years, 41.3% 60–69 years, 40.4% 70–79 years, 16.4% 80–89 years, 1.9% ≥90 years). Nearly two-thirds of the sample was female (62%). The sample largely identified as non-Hispanic White (74%). Based on BMI recommendations for older adults (Porter Starr & Bales, 2015; Winter, MacInnis, Wattanapenpaiboon, & Nowson, 2014), 22.3% of the sample was classified as underweight (i.e. <23.0 kg/m^2), 51.5% was classified as normal/overweight (23.0–29.9 kg/m^2), and 26.2% was classified as obese (>30.0 kg/m^2). Additionally, 71.2% of the sample indicated that they were retired, 15.4% indicated they were working full time, 10.6% indicated they were working part time, and 1.9% indicated they were unemployed. One participant did not provide self-reported height, weight (and therefore unable to calculate BMI), or employment status. Almost all participants reported living independently in a home or apartment (94%).

Descriptive statistics

Averaging across all occasions, older adults in this sample tended to sit for the majority of the two hours following the EMA prompt (M = 77.0 min, SD = 29.6, Median = 82.2 min, Skew = −.60). Examining participant's log-reported sleep and wake times along with ActivPAL data indicated that on average, participants engaged in more than 10 h of sedentary behavior during waking hours each day (M = 10.4 h, SD = 2.1). Older adults spent, on average, 11 min of each two-hour window stepping (M = 11.5 min, SD = 11.4). Older adults also tended to display moderate levels of intentions and self-efficacy to limit time spent sitting (M = 3.2, SD = 1.0, M = 3.7, SD = 1.0, on a 1 to 5 scale). Older adults reported moderate-to-strong habit strength for engaging in sedentary behavior (M = 4.8, SD = 1.5, on a 1 to 7 scale).

To provide further descriptive details, correlations among key variables were examined. Not taking into account dependency across occasions, sedentary behavior in the two hours after the prompt was negatively correlated with intentions ($r = -.32$, $p < .001$) and self-efficacy ($r = -.28$, $p < .001$) to limit time spent sitting over the next two hours, whereas sedentary behavior in the two hours after the prompt was positively correlated with habit strength ($r = .15$, $p < .001$).

Multilevel modeling

Table 1 presents parameter estimates of fixed effects and standard errors from the linear multilevel model predicting minutes of sedentary behavior in the two hours following the EMA prompt. Older adults engaged in less sedentary behavior on occasions when their intentions ($\gamma_{10} = -1.63$, $p = 0.02$) as well as self-efficacy ($\gamma_{20} = -2.01$, $p = 0.003$) to limit their sedentary behavior were stronger than usual (i.e. within-person associations); however, older adults' sedentary behavior was not associated with older adults' intentions ($\gamma_{01} = -5.30$, $p = 0.05$) or self-efficacy ($\gamma_{02} = 2.77$, $p = 0.27$) to limit sedentary behavior at the between-person level. Older adults with stronger sedentary behavior habit strength tended to engage in greater sedentary behavior in the two hours following the EMA prompt ($\gamma_{03} = 2.04$, $p = 0.006$).

Greater levels of physical activity were associated with less sedentary behavior at both the between-person ($\gamma_{04} = -1.46$, $p < 0.001$) and within-person ($\gamma_{30} = -1.52$, $p < 0.001$) level. Older adults tended to engage in lower levels of sedentary behavior on weekend days compared to weekdays ($\gamma_{40} = -1.81$, $p = 0.003$). Additionally, older adults engaged in higher levels of sedentary behavior later in the day compared to earlier in the day ($\gamma_{50} = 4.00$, $p < 0.001$). Older adults with greater overall physical functioning tended to engage in less sedentary behavior ($\gamma_{09} = -0.11$, $p = 0.04$). No differences in sedentary behavior in the two hours following the EMA prompt were noted between men and women ($\gamma_{05} = -1.72$, $p = 0.42$), older adults of different ages ($\gamma_{06} = -0.28$, $p = 0.10$), older adults with different BMI values ($\gamma_{07} = 0.22$, $p = 0.34$), or older adults working compared to not working ($\gamma_{08} = -1.71$, $p = 0.51$).

Discussion

This study is the first to investigate the motivational processes regulating older adults' momentary sedentary behavior. Study findings add to accumulating evidence that health behaviors are regulated by both conscious and non-conscious motivational processes (e.g. Hagger, 2016; Rebar et al., 2016). Additionally, results from this study highlight the importance of investigating these motivational processes at the between- and the within-person level as associations were not consistent across both levels. Taken together, these results highlight the novel insights that can be gained in the prediction and modeling of sedentary behavior using real-time data capture methodology in the context of everyday life.

Habit strength for sedentary behavior, a non-conscious motivational process, was a key predictor of older adults' momentary sedentary behavior, even after controlling for conscious motivational processes including intentions and self-efficacy. Previous research across the lifespan has documented the powerful role that habits can play in regulating health behaviors (Rebar et al., 2016; Sheeran et al., 2013; van't Riet, Sijtsema, Dagevos, & De Bruijn, 2011). Conroy et al. (2013) and Maher and Conroy (2016) previously found that sedentary behavior habit strength was positively associated with daily sedentary behavior in college students and older adults, respectively. This is the first study to document a positive association between sedentary behavior habit strength and momentary sedentary behavior. Although sedentary behavior habit strength represents a non-conscious process, current best practices to assess this construct rely on conscious, self-reflection through the Self-Report Behavioural Automaticity Index (Gardner et al., 2012). Assessing a non-conscious process with a tool that requires conscious awareness of the phenomenon of interest may limit the validity of the assessment (Rebar, Gardner, Rhodes, & Verplanken, 2018). Implicit measures of habit have been touted as the gold standard of habit measurement because such measures are indirect assessments that do not rely on subjective assessments and introspection (Gardner, 2015). However, implicit measures of habit are still in their infancy and often assess the automaticity of habits as opposed to habits themselves (Danner, Aarts, Papies, & de Vries, 2011; Orbell & Verplanken, 2010). EMA paired with passive sensors may represent a possible avenue to assess non-conscious habitual processes by capturing contextual cues (e.g. time of day, physical context, social context, affective state) and habitual responses to those contextual cues that impact behavior. Specifically, event-contingent EMA prompting could offer another approach to assess habits by capturing the frequency of a behavior as well as the extent to which a person engages in a behavior consistently in same context. Both the frequency of a behavior as well as the consistency of the contextual cues surrounding that behavior are thought to be important determinants of habit strength (Wood, Tam, & Witt, 2005).

Habits develop through the repeated paring of a cue in the environment with a behavioral response so that over time encountering the cue produces an impluse to engage in the behavior (Aarts & Dijksterhuis, 2000; Aarts et al., 1997). Older adults could potentially have the longest amount of time to develop these habitual, automatic pairings between cues in the environment with the behavioral response. It is possible that older adults' behaviors are more likely to be driven by, or susceptible to being driven by, habitual, non-conscious processes (Aarts et al., 1997; Verplanken et al., 2008). Action planning represents a promising intervention strategy to disrupt habitual responses associated with encountering a contextual cue that typically elicits a behavioral response. Action plans specify a behavioral response in a given context with the thought that individuals are more likely to follow the behavioral response in line with their intentions and plan when they encounter a context previously associated with an unwanted habitual response (Wood & Neal, 2016). Maher and Conroy (2016) found that strength of older adults' action plans (i.e. when, where, and how) to limit sedentary behavior at the beginning of the day were negatively associated with sedentary behavior accumulated during that day. Action planning has previously been found to be a promising intervention strategy for reducing sedentary behavior among adults (Gardner, Smith, Lorencatto, Hamer, & Biddle, 2016). Though preliminary evidence suggests that the effectiveness of daily action planning on subsequent health behaviors may differ by habit strength (Maher & Conroy, 2015). It is unclear the extent to which developing action plans to enact over the next few hours to change health behaviors would be effective. Other intervention strategies that may be effective in breaking unwanted habits include environmental re-engineering that would add behavioral friction to an existing behavioral response such as removing one's favorite arm chair or making the chair uncomfortable to sit in for long periods of time (Wood & Neal, 2016). Vigilant monitoring may also be effective in disrupting unwanted habits as this strategy aims to increase awareness and heighten inhibitory control processes in context when an individual may be most susceptible to succumbing to unhealthy habits (Wood & Neal, 2016).

Regarding conscious motivational processes, intentions and self-efficacy to limit sedentary behavior were negatively associated with sedentary behavior in the subsequent two hours at the within-person, but not the between-person, level. These results highlight the importance of disaggregating between-person and within-person processes. These findings suggest the possibility that previous research regarding between-person associations among psychological factors and sedentary behavior (e.g. Chastin et al., 2015) may be driven by unaccounted for within-person processes. Results from the current study suggest the importance of enhancing intentions or self-efficacy to reduce sedentary behavior at key moments, rather than delivering intervention content to enhance overall levels of intentions or self-efficacy. Furthermore, just-in-time adaptive interventions could capitalize on these findings by delivering intervention content that can help translate higher-than-usual intentions or self-efficacy to limit sedentary behavior into behavior change. An example of such just-in-time adaptive intervention content might be, when an older adult reports higher-than-usual intentions to limit sedentary behavior over the next two hours, to prompt older adults with a report on their recent behavior to activate the self-regulatory strategy of self-monitoring to facilitate the translation of intentions into behavior. Additionally, when an older adult reports lower-than-usual self-efficacy along with feelings of fatigue or low arousal, testimonial messages from an older adult who was able to find ways to break up their sedentary behavior even when they were experiencing fatigue or boredom could be delivered to help boost feelings of self-efficacy through modeling.

Although this study assessed and evaluated the impact of dual processes of motivation on older adults' sedentary behavior, there are still other non-conscious and conscious motivational processes that need to be examined in future research. For instance, implicit attitudes or automatic evaluations represent the strength of a person's automatic association between the concept such as sedentary behavior and feelings of pleasantness or unpleasantness (Chen & Bargh, 1999; Greenwald & Banaji, 1995). Therefore, implicit attitudes predispose a person to actively respond to those cues of pleasantness or unpleasantness with approach or avoidance behavioral tendencies, respectively (Chen & Bargh, 1999). To date, limited research has been conducted regarding implicit attitudes toward sedentary behavior but accumulating evidence indicates that positive implicit attitudes towards physical activity are associated with higher levels of physical activity behavior even after controlling for conscious motivational processes (Conroy & Berry, 2017; Rebar et al., 2016). Furthermore, as previously mentioned, action planning is a conscious motivational process thought to disrupt habitual behavior responses by helping to bridge the gap between counterhabitual intentions and subsequent behavior (de Bruijn, Rhodes, & van Osch, 2012). Future research would benefit from systematically exploring these conscious and non-conscious motivational processes to better understand the mechanisms that regulate older adults' sedentary behavior.

Limitations

The limitations of this study should be acknowledged. Although our sample represented an at-risk group, engaging in more than 10 waking hours of sedentary behavior per day on average, the sample consisted of mostly females as well as individuals identifying as white. Additionally, although participants indicated a range of socioeconomic levels, the majority of participants indicated earning above the median household income for Los Angeles county. It is possible that within-person patterns of sedentary behavior as well as the motivational processes that influence sedentary behavior may differ among more diverse groups. For instance, low-income and minority adults tend to engage in higher levels of sedentary behavior (Evenson et al., 2014; Shuval et al., 2013) and the motivational factors that contribute to sedentary behavior may differ. It is also possible that some of these demographic factors such as sex, ethnicity or age may serve as moderators of associations between conscious and non-conscious processes and behavior. Understanding the nuances of these conscious and non-conscious processes in regulating sedentary behavior in different sub-samples represents an important direction for future research.

With respect to measures, standards have yet to be established for determining the cutoff for valid wear time within a window of time following an EMA prompt. Our study mirrored several recent studies combining EMA and accelerometry that used a minimum cut off where if more than half of the window following the EMA prompt was identified as non-wear, the window was not considered valid and eliminated from the analytic sample (Maher et al., 2016, 2017). More research is necessary to determine the appropriate amount of wear time necessary to provide an accurate representation of behavior during specific time intervals. Furthermore, it is possible that participants removed the activity-monitor to complete water-based activities such as swimming or water aerobics but that that time was considered valid sedentary behavior if participants were able to wear the activity monitor for at least 60 min in the 120 min after the EMA prompt. We expect that such occasions were rare because approximately three-fourths of our sample ($n = 75$, 72%) indicated through the activity monitor log that they never removed the activity monitor during the study and of those that did remove the monitor, approximately half ($n = 14$) removed the monitor for less than 60 min total over the course of the study. However, it is possible that associations between motivation and subsequent sedentary behavior were attenuated due to potential misclassification of behavior. Additionally, EMA items to assess intentions and self-efficacy to limit sedentary behavior were single-item measures. Single-item or brief measures are often necessary in EMA studies due to the intensive nature of the sample protocol and the need to reduce participant fatigue and burden associated with the intensive, repeated assessments. These single-item measures were adapted from previous EMA studies of physical activity and sedentary behavior (Maher & Conroy, 2016; Pickering et al., 2016); however, it is possible that these items do not fully capture the intention or self-efficacy construct. Furthermore, the self-efficacy item employed a scale that captured the level of agreement with the item as opposed to the level of confidence in achieving the behavioral target of the item (Bandura, 2006). Future research should explore the implications of assessing momentary self-efficacy with scales gauging level of confidence versus level of agreement. Finally, regarding measurement, it is possible that intensive assessment of motivation for limiting sedentary behavior may lead to reactivity in terms of subsequent motivation or behavior; however, evidence of reactivity to EMA protocols is mixed (Barta, Tennen, & Litt, 2012). Exploring issues of reactivity in activity-related EMA protocols is an important direction for future research (Ram, Brinberg, Pincus, & Conroy, 2017).

With respect to data analysis, rates of missing data in our sample differed by sex and day of week. Although we controlled for sex and day of week in our analysis, associations documented in this study may be influenced by this systematic missingness. Additionally, multilevel models conducted in this study assume a linear relationship between motivational constructs and sedentary behavior; however, recent research has documented temporal variation in the associations between motivational constructs and subsequent physical activity (Maher & Dunton, 2019; Maher et al., 2016). Additionally, there may be contextual factors that strengthen or attenuate within-person associations between motivation and behavior (e.g. affective state, social context, physical location; Dunton, 2017; Maher et al., 2017) Therefore, future research examining the extent to which associations between sedentary behavior and motivation change across time and contexts may be particularly useful for the development of just-in-time adaptive interventions.

Conclusions

This study demonstrated that older adults' sedentary behavior is regulated by both conscious and non-conscious motivational processes. This work emphasizes the importance of future research to conceptualize sedentary behavior motivation through a dual-process lens. Results from this study indicate that by moving beyond mean levels of motivation and behavior, important information regarding the behavioral dynamics can be gleaned and used in interventions. Specifically, findings from this study suggest interventions to reduce older adults' sedentary behavior should integrate content targeting momentary intention formation and enhancing momentary self-efficacy beliefs to limit sitting as well as content to disrupt habitual sedentary behavior. Designing theory-based, effective interventions to reduce older adults' sedentary behavior are critically needed given the excessive amount of sedentary behavior most older adults engage in as well as the impending silver tsunami of aging adults.

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Table 1.

Multilevel linear regression model predicting time spent sitting in the two hours after the EMA prompt.

	Parameter estimate (Standard error)
Fixed effects	
Intercept	71.32** (1.97)
Between-person intentions to limit sedentary behavior	−5.30 (2.70)
Within-person intentions to limit sedentary behavior	−1.64* (0.68)
Between-person self-efficacy to limit sedentary behavior	2.77 (2.51)
Within-person self-efficacy to limit sedentary behavior	−2.01** (0.68)
Sedentary behavior habit strength	2.04** (0.73)
Between-person physical activity	−1.46** (0.24)
Within-person physical activity	−1.52** (0.03)
Age	−0.28 (0.17)
Sex (Female)	−1.72 (2.15)
BMI	0.22 (0.24)
Employment status (Working at all)	−1.72 (2.62)
Physical functioning	−0.11 (0.05)
Time of day	4.00** (0.33)
Weekend day	−1.81** (0.62)
Random effects	
Variance intercept	97.72** (14.56)
Variance intentions to limit sedentary behavior	15.03** (4.36)
Variance self-efficacy to limit sedentary behavior	12.49** (4.03)
Residual	365.57** (7.14)

Note. Multilevel model based on 5465 observations from 103 people.

* $p < 0.05$.

** $p < 0.01$.