# A dual-process model of older adults' sedentary behavior

By: Jaclyn P. Maher, David E. Conroy

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**Abstract:**

**Objective:** This 14-day daily diary study tested a dual-process model of motivation to determine the between-person (time-invariant) and within-person (time-varying) processes associated with older adults' daily sedentary behavior. This model integrated the health action process approach (HAPA) with research on habit strength. **Method:** Older adults (n = 100) answered questions regarding their motivation and behavior at the beginning and end of each day, respectively. Participants also wore ActivPAL3 activity monitors for the duration of the study. **Results:** Multilevel models predicting behavior revealed that sedentary behavior was (a) negatively associated with planning to reduce sedentary behavior at the within-person (but not the between-person) level, and (b) positively associated with sedentary behavior habit strength. Plans to limit sedentary behavior were (a) positively associated with task self-efficacy at the within-person level, but (b) negatively associated at the between-person level, and (c) positively associated with intentions at the between- and within-person level. Intentions to limit sedentary behavior were (a) positively associated with task self-efficacy at the between and within-person level, but (b) not associated with light-intensity physical activity outcome expectations, sedentary behavior risk perceptions, or sedentary behavior habit strength. **Conclusions:** This study was the first to systematically investigate a combination of controlled and automatic processes that are associated with daily fluctuations in older adults' sedentary behavior. Interventions aiming to reduce sedentary behavior in older adults should target the motivational constructs identified in this study to provide the best chance for behavior change.

**Keywords:** sitting | aging | intraindividual | motivation

**Article:**

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Excessive sedentary behavior, or time spent sitting, has been linked with increased risk for a variety of negative health consequences (Biswas et al., 2015; de Rezende, Rey-López, Matsudo, & do Carmo Luiz, 2014). Older adults are particularly susceptible to these adverse outcomes because they sit more than any other segment of the population. Older adults, on average, sit for more than nine waking hours per day (Harvey, Chastin, & Skelton, 2014).

Attempts to reduce older adults' sedentary behavior have largely targeted controlled motivational processes (e.g., intentions or self-efficacy to engage in physical activity) previously found to predict physical activity (King et al., 2013; Rosenberg et al., 2015). It is unclear if these controlled motivational processes are associated with sedentary behavior (e.g., intentions or efficacy to limit sedentary behavior) because there has yet to be a study that systematically investigates these controlled processes as they relate to sedentary behavior. Given that sedentary behavior and physical activity are distinct health behaviors, the processes that regulate these health behaviors may differ. This study examines older adults' sedentary behavior through a dual-process lens which considers both the controlled and automatic processes that regulate behavior.

## MOTIVATION UNDERLYING SEDENTARY BEHAVIOR

Dual-process theories of motivation posit that both controlled and automatic processes regulate our behavior (Hofmann, Friese, & Wiers, 2008). Controlled processes are conscious, effortful, and slow and include constructs outlined in social-cognitive theories of motivation (e.g., intentions). Automatic processes are relatively nonconscious, effortless, and fast and can include constructs like habits. Habits develop through the repeated pairing of a contextual cue and a behavioral response so that, over time, encountering the cue automatically elicits the behavioral response (Aarts, Paulussen, & Schaalma, 1997). These cues can take a variety of forms including a physical object, environment/location, time of day, emotional state, or even a combination of these. One such example may be that when a person watches TV (i.e., the cue) they are motivated by an impulse to sit in their favorite armchair (i.e., the behavioral response). Such an automatic process is believed to be the result of repeated occasions in the past when the individual was reinforced for this cue-behavior pattern (i.e., watching TV while sitting in a favorite armchair; Neal, Wood, & Quinn, 2006). Both controlled and automatic motivational processes may exert an influence on older adults' sedentary behavior.

Evidence of the regulation of sedentary behavior via dual processes exists in college students (Conroy, Maher, Elavsky, Hyde, & Doerksen, 2013). Specifically, this work documented that (a) both sedentary behavior and intentions to limit sedentary behavior varied within people over time, and (b) intentions to limit sedentary behavior (at both the between- and within-person level) and habit strength were significant predictors of behavior.

Concerning dual processes in older adults, older adults have the greatest potential to develop strong habits for sedentary behavior because they have had more time to develop an association between contextual cues and sedentary behavior (Verplanken, Walker, Davis, & Jurasek, 2008). Strong habits are likely to initiate a behavioral response automatically and effortlessly within a

person unless the person intervenes by exerting self-control to pursue a counterhabitual goal (Rebar, Elavsky, Maher, Doerksen, & Conroy, 2014). For example, an individual may have a strong habit for sitting while taking the metro to work; however, on a given day this individual may decide that she would like to stand rather than sit on the metro. Therefore, she makes a detailed plan that specifies elements of the context (e.g., when, where) as well as her behavioral response (e.g., how), resulting in a plan that states "in the morning while on my way to work, I will stand while on the metro." By making a plan that details these contextual cues and the individual's new behavior response, she is more likely to follow through with her planned, rather than habitual response, when encountering those cues (Hagger & Luszczynska, 2014). Sedentary habits have not been investigated in older adults; however, qualitative work indicates that older adults believe controlled processes, such as self-efficacy, are determinants of their behavior (Chastin, Fitzpatrick, Andrews, & DiCroce, 2014).

Based on evidence of an intention-behavior gap for sedentary behavior (Conroy, Maher, et al., 2013), it is important to expand the scope of controlled processes to include volitional processes, which have proven to play a role in translating intentions into behavior. The Health Action Process Approach (HAPA) is an ideal theoretical framework to serve as the basis for explaining the controlled processes that regulate older adults' sedentary behavior. HAPA outlines the processes that lead to intention formation as well as the processes that translate intentions into behavior (thus overriding habitual behaviors; Schwarzer, 2008; Schwarzer et al., 2007; Sniehotta, Scholz, & Schwarzer, 2005; Ziegelmann, Lippke, & Schwarzer, 2006).

HAPA, like other social-cognitive theories, posits that intention formation is regulated by three common motivational constructs (Schwarzer, 2008; Schwarzer et al., 2007). The first, *task self-efficacy*, refers to the extent to which a person believes they can successfully complete a behavior (Bandura, 1997; Marlatt, Baer, & Quigley, 1995). The second, *outcome expectations*, refer to the extent to which a person believes engaging in a behavior can result in a desired outcome (Bolles, 1972). The third, *risk perceptions*, refer to the extent to which a person believes engaging in a behavior can result in an undesired outcome (Bolles, 1972). Additionally, work on the habit-goal interface suggests that intentions may be inferred from habits (Wood & Neal, 2007). Sedentary behavior habit strength may play a role in intention formation to limit sedentary behavior and therefore will be considered an additional predictor of intentions in the motivational phase of HAPA.

HAPA, also recognizes that developing intentions is often not sufficient to change behavior—a phenomenon known as the intention-behavior gap (Sheeran, 2002). Volitional processes, like planning (Gollwitzer & Sheeran, 2006; Ziegelmann & Lippke, 2007), are crucial in translating intentions into behavior. *Action planning* involves specifying the details of when, where, and how to act in the service of one's intentions (Gollwitzer, 1999; Leventhal, Singer, & Jones, 1965). *Coping planning* involves identifying how one will overcome obstacles that could interfere with the goal striving process (Scholz, Sniehotta, Burkert, & Schwarzer, 2007; Sniehotta, Schwarzer, Scholz, & Schüz, 2005). In addition to intentions, HAPA also proposes that task self-efficacy influences planning.

Applying this extended HAPA + habit model to predict behavior will provide the most complete dual-process model to date of the processes associated with sedentary behavior. Other volitional

processes that contribute to behavior include maintenance and recovery self-efficacy and perceived barriers and resources. These constructs focus on a person's ability to maintain behavior change in the face of barriers and relapses (Luszczynska & Sutton, 2006); however, this study is not focused on initiating behavior change so these constructs were not included in this study.

## DISTINGUISHING TIME-VARYING AND TIME-INVARIANT MOTIVATIONAL PROCESSES

Many of the motivational constructs that regulate sedentary behavior can change from day to day in response to daily obligations or the social calendar (Greenwood-Hickman, Renz, & Rosenberg, 2015; Marshall et al., 2014). For instance, daily changes in intentions to limit sedentary behavior covary with changes in daily sedentary behavior (Conroy, Maher, et al., 2013). However, it is also possible that older adults are more susceptible to lack of variation in their behavioral patterns due to increased health problems and reduced social interactions and mobility (Miller, Rejeski, Reboussin, Ten Have, & Ettinger, 2000). There is limited work documenting the time-varying nature of motivation in older adults. Both time-invariant (i.e., differentiating people who engage in more vs. less sedentary behavior overall) and time varying processes (i.e., differentiating days when people engage in more vs. less sedentary behavior) should be considered when investigating the processes that regulate older adults' sedentary behavior.

Considering previous findings as well as the unique challenges faced by older adults, daily intentions, task self-efficacy, and plans to limit sedentary behavior and behavior are assumed to be time-varying phenomena within older adults (Conroy, Elavsky, Hyde, & Doerksen, 2011; Conroy, Maher, et al., 2013). Conversely, beliefs about the consequences associated with health behaviors and habits develop over time and are resistant to change (Lally, van Jaarsveld, Potts, & Wardle, 2010). Thus, light-intensity physical activity outcome expectations, sedentary behavior risk perceptions, and sedentary behavior habit strength are assumed to be time-invariant over a brief period (absent an intervention targeting these factors). This study will be the first application of a dual-process model that considers both time-varying (i.e., within-person) and time-invariant (i.e., between-person) influences on older adults' sedentary behavior.

## THE PRESENT STUDY

To investigate the time-varying and time-invariant processes that regulate older adults' sedentary behavior, a 14-day ecological momentary assessment study employing both daily diary and ambulatory monitoring methods was conducted. Hypotheses were based on the extended HAPA + habit model shown in the top panel of Figure 1. Sedentary behavior was hypothesized to be (a) negatively associated with usual and daily plans to limit sedentary behavior, and (b) positively associated with habit strength. Plans to limit sedentary behavior were hypothesized to be positively associated with usual and daily intentions and task self-efficacy to limit sedentary behavior. Intentions to limit sedentary behavior were hypothesized to be (a) positively associated with usual and daily task self-efficacy to limit sedentary behavior and light-intensity physical activity outcome expectations, and (b) negatively associated with sedentary behavior risk perceptions and habit strength. In testing these hypotheses potential time-varying and time-

invariant confounds were controlled, including daily physical symptoms, the day-of-week, time-in-study, usual physical activity, usual physical symptoms, sex, and body mass index (BMI). Additionally, usual and daily physical activity were controlled in the models predicting daily sedentary behavior.

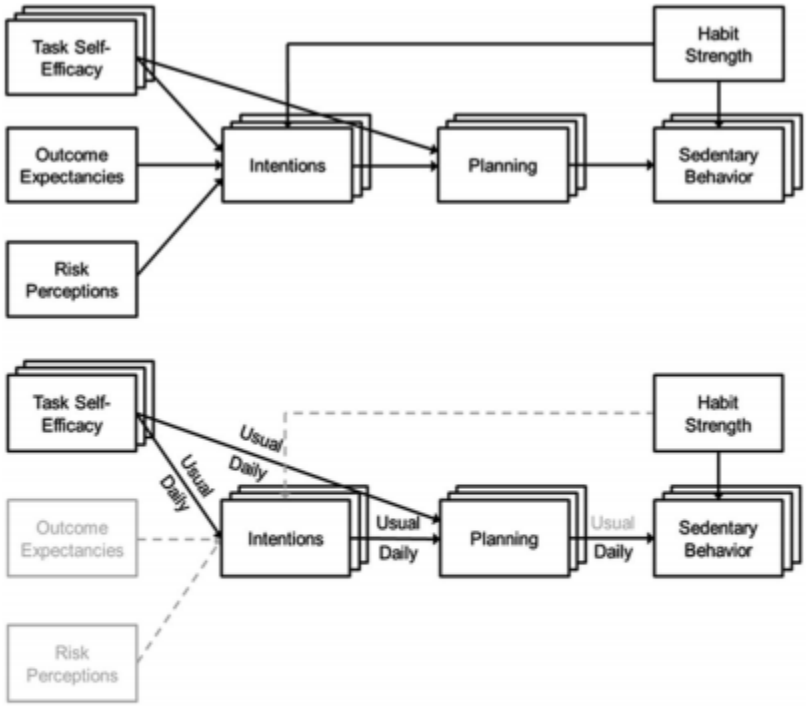


*Figure 1.* (top) Proposed dual-process model to predict older adults' sedentary behavior. Task self-efficacy, intentions, planning, and behavior were considered time-varying, were subject to repeated, daily assessment, and are represented by the repeated boxes. Outcome expectancies for light-intensity physical activity, risk perceptions for sedentary behavior, and sedentary behavior habit strength were considered time-invariant, assessed at baseline, and are each represented by a single box. (bottom) Revised dual-process model based on study findings. Significant paths are in black ($p < .05$). Nonsignificant paths are in gray ($p > .05$).

## METHOD

### Participants

Community-dwelling older adults ($n$ = 114) expressed an interest in participating in the study and were screened for eligibility. Participants were included if they were age 60 or older and reported sitting an average of ≥8 hr/day; they were excluded if they had been diagnosed by a physician as having dementia or Alzheimer's disease or reported any deficit in functional mobility as assessed by the walking and transferring subscales of the Instrumental Activities of Daily Living Scale (Lawton & Brody, 1969). Eligible participants ($n$ = 109) were scheduled to attend an initial session but nine dropped out prior to study completion (7 cancelled prior to the first lab visit, 1 dropped out immediately after the first lab visit because of perceived burden, 1 participant's tablet computer malfunctioned causing complete data loss). The final sample included women ($n$ = 67) and men ($n$ = 33) and was almost exclusively White (99%) and non-Hispanic (99%). Participants ranged from 60 to 89 years ($M$ = 74.2 years; $SD$ = 8.2) and, based

on BMI (*M* = 27.3, *SD* = 5.3), were relatively evenly split between normal weight (39%), overweight (37%), and obese (24%).

## Procedures

Participants attended an initial session where they were familiarized with the study procedures and equipment to be used in the study, provided written informed consent, and assigned a tablet computer and an ActivPAL3 activity monitor. Participants learned how to use the tablet to complete questionnaires at the beginning and end of each day and how to affix the activity monitor to the front of their lower thigh. Finally, participants completed a brief questionnaire assessing demographic information (i.e., age, sex, race, ethnicity, height, and weight), light-intensity physical activity outcome expectations, sedentary behavior risk perceptions, and sedentary behavior habit strength. Over the next 14 days participants completed questionnaires on their tablet at the beginning (measures included daily task self-efficacy, intentions, planning to limit sedentary behavior, sleep/wake times) and end of each day (measures included domain-specific sedentary time, physical activity, physical symptoms) and wore the activity monitor on their thigh during all sleeping and waking hours. Monitors were waterproofed to allow for continued wear while showering; however, participants were asked to remove the monitor any time it would be submerged under water (i.e., bathing, swimming). On Day 14 participants returned the study equipment. All procedures were approved by the local institutional review board.

## Measures

### *Sedentary behavior*

Daily self-reported sedentary behavior was assessed using a 9-item scale which featured domain-specific sedentary activities included in other validated measures of older adults' sedentary behavior (i.e., watching TV, using the computer, reading, socializing with friends, in transit, completing hobbies, doing paperwork, eating, or any other activities; Gardiner et al., 2011; Visser & Koster, 2013). Items were modified to reflect daily sedentary time to reduce the threat of retrospective bias and recall errors (Matthews, Moore, George, Sampson, & Bowles, 2012). Responses were summed to create a daily sedentary behavior score.

Objectively measured sedentary behavior was assessed using ActivPAL3 activity monitors (Physical Activity Technologies, Glasgow, Scotland) which have 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). The ActivPAL3 monitor uses a three-dimensional accelerometer, which in conjunction with the monitor's placement on the front of participant's thigh essentially allows the monitor to acts as an inclinometer, to measure posture and activity, respectively, and then uses proprietary algorithms to classify time as time spent sitting or lying, standing, and stepping. Additionally, because of the waterproofing and unique placement of the monitor on the thigh (held in place by a 4 in. × 4 in. piece of medical tape), the ActivPAL3 monitor is not susceptible to common nonwear issues associated with waist-worn accelerometers. Nevertheless, participants were provided with logs to record the times they were not wearing the activity monitor as well as the reason for the nonwear

time. Time spent sleeping was subtracted from daily objectively measured sedentary behavior to determine the amount of time each day spent sitting or lying down while awake. Data were screened to identify valid days. Following established conventions, a valid day of recording consisted of ≥10 hr of valid waking wear time with logs and accelerometer data (i.e., every period of 60 consecutive minutes of zeros) used to determine nonwear time.

*Planning*

Daily action and coping planning to limit sedentary behavior were assessed using four items (Sniehotta, Scholz, et al., 2005). Participants rated each item using a slider-type interface and ratings were coded from 0 (*not at all*) to 100 (*very much*) scale. Action and coping planning items were highly correlated (*r*s = .81–.91) so a composite item was created.

*Intentions*

Daily intentions to limit sedentary behavior were assessed using a 2-item measure adapted from previous research (Conroy, Maher, et al., 2013). Participants used a slider-type interface to rate items and ratings were digitally coded from 0 (*do not intend at all*) to 100 (*strongly intend*). Responses to these two items were strongly correlated (*r*s = .64–.80) so an average intention item was created.

*Task self-efficacy*

Participants rated their confidence that they could limit their sedentary behavior each day using a 2-item measure adapted from previous research (Conroy, Maher, et al., 2013). Ratings were made using a slider-type interface and responses were coded from 0 (*not at all confident*) to 100 (*very confident*). Responses were strongly correlated (*r*s = .62–.70) and therefore averaged to create a task-self-efficacy item.

*Outcome expectations*

Outcome expectations for light-intensity physical activity were assessed using a modified, 7-item version of the Multidimensional Outcome Expectations for Exercise Scale (Wójcicki, White, & McAuley, 2009). This scale was modified to focus on outcome expectations from light-intensity physical activity and to exclude items focused on health outcomes without clear links to light physical activity (e.g., bone strength, muscular strength, stress management). Participants responded on a 0 (*strongly disagree*) to 4 (*strongly agree*) scale. Responses were internally consistent ($\alpha$ = .91).

*Risk perceptions*

Sedentary behavior risk perceptions were assessed using an 8-item scale created for this study based on health risks associated with excessive sedentary behavior in recent reviews (Biswas et al., 2015; de Rezende et al., 2014). Participants rated how strongly they believed that sitting for more than 8 waking hours each day would lead to poor health outcomes (e.g., premature death)

on a 0 (*strongly disagree*) to 4 (*strongly agree*) scale. Responses were internally consistent (α = .89).

*Sedentary behavior habit strength*

Sedentary behavior habit strength was measured using the 4-item automaticity subscale of the Self-Reported Habit Index (Gardner, Abraham, Lally, & de Bruijn, 2012; Verplanken & Melkevik, 2008; Verplanken & Orbell, 2003). Participants rated items on a scale ranging from 0 (*strongly disagree*) to 4 (*strongly agree*). Responses were internally consistent (α = .89).

*Physical activity*

Daily self-report physical activity was assessed using a modified version of the International Physical Activity Questionnaire (IPAQ), a validated measure of physical activity in adults and older adults (Booth, 2000; Craig et al., 2003; Grimm, Swartz, Hart, Miller, & Strath, 2012). The IPAQ was modified to focus on daily instead of weekly physical activity. This daily adaptation likely reduced the threat of retrospective bias and recall errors and has been used in previous research (Maher, Doerksen, Elavsky, & Conroy, 2014; Matthews et al., 2012). Standard scoring procedures for the IPAQ were used to convert duration of reported activities into metabolic equivalents. Activity times were weighted by standard metabolic equivalent of task (MET) estimates (vigorous = 8, moderate = 4, walking = 3.3) and summed to create a daily PA MET·min score (Sjöström et al., 2002, 2005). Objectively measured physical activity was measured using the ActivPAL3 activity monitor (described above). Physical activity was defined as time spent stepping.

*Physical symptoms*

Physical symptoms were assessed using a modified version of the physical symptoms checklist (Larsen & Kasimatis, 1991). Participants rated four items corresponding to the severity of major symptoms (i.e., musculoskeletal, gastrointestinal, cold and flu, and cardiorespiratory) on a 0 (*not at all*) to 100 (*very much*) scale that used a slider-type interface. Responses were weakly to-moderately correlated (*r*s = .23–.43) and not internally consistent (α = .56) so each physical symptom was treated as a separate predictor.

*Temporal processes*

To control for the possibility that motivation or behavior changed as a result of, or was reactive to, participating in the study a within-person variable representing *exposure to the protocol* was created. The exposure variable accounted for the day in study. Second, six dummy variables were created representing the days of the week to account for possible effects of the *social calendar*. Saturday served as the reference day because it had the lowest grand mean for sedentary behavior.

*Data Analysis Plan*

Multilevel models (e.g., Snijders & Bosker, 1999) were used to examine associations at the between- and within-person level while accounting for the nested structure of the data. All models were estimated using SAS 9.3 PROC MIXED (Littell, Milliken, Stroup, & Wolfinger, 1996) with restricted maximum likelihood estimation, treating the small amount of incomplete data as missing at random. Data from the first day of the study were eliminated from analyses due to incomplete data on those days, resulting in a 13-day sample of motivation and behavior. Following standard multilevel modeling practices, pseudo-$R^2$, the additional proportion of variance explained by the predictors compared to a baseline model, was computed as an effect size (Snijders & Bosker, 1999).

*Data preparation*

Daily ratings of time-varying predictor variables (e.g., task self-efficacy) were aggregated and person-mean centered to separate and simultaneously test between- and within-person associations (Bolger & Laurenceau, 2013; Enders & Tofighi, 2007). At the between-person level of analysis, within-person mean scores across the 13 days differentiated between *people* with higher or lower task self-efficacy. At the within-person level of analysis, daily deviations from corresponding within-person means differentiated *days* on which people had higher or lower task self-efficacy than usual. Age and BMI were group-mean centered, and exposure to study was cluster-mean centered.

*Multilevel models*

Multilevel models were used to accomplish the objectives outlined. The multilevel model used to predict sedentary behavior is outlined by Equations 1 through 4:

$$\begin{aligned}\text{Level 1: Sedentary behavior}_{di} = {} & \beta_{0i} + \beta_{1i}(\text{daily planning}_{di}) \\ & + \beta_{2i}(\text{daily physical activity}_{di}) \\ & + \beta_{3i}(\text{daily musculoskeletal symptoms}_{di}) \\ & + \beta_{4i}(\text{daily gastrointestinal symptoms}_{di}) \\ & + \beta_{5i}(\text{daily cold/flu symptoms}_{di}) \\ & + \beta_{6i}(\text{daily cardiorespiratory symptoms}_{di}) + \beta_{7i}(\text{Monday}_{di}) \\ & + \beta_{8i}(\text{Tuesday}_{di}) + \beta_{9i}(\text{Wednesday}_{di}) + \beta_{10i}(\text{Thursday}_{di}) \\ & + \beta_{11i}(\text{Friday}_{di}) + \beta_{12i}(\text{Sunday}_{di}) + \beta_{13i}(\text{study day}_{di}) + e_{di} \end{aligned} \tag{1}$$

$$\begin{aligned}\text{Level 2: } \beta_{0i} = {} & \gamma_{00} + \gamma_{01}(\text{usual planning}_i) + \gamma_{02}(\text{habit strength}_i) \\ & + \gamma_{03}(\text{usual physical activity}_i) \\ & + \gamma_{04}(\text{usual musculoskeletal symptoms}_i) \\ & + \gamma_{05}(\text{usual gastrointestinal symptoms}_i) \\ & + \gamma_{06}(\text{usual cold/flu symptoms}_i) \\ & + \gamma_{07}(\text{usual cardiorespiratory symptoms}_i) \\ & + \gamma_{08}(\text{sex}_i) + \gamma_{09}(\text{age}) + \gamma_{010}(\text{BMI}_i) + u_{0i} \end{aligned} \tag{2}$$

$$\beta_{1i} = \gamma_{10} + \ + u_{1i} \tag{3}$$

$$\beta_{(2-13)i} = \gamma_{(2-13)0} \tag{4}$$

where $\gamma_{00}$ represents the average level of sedentary behavior for the average person in the sample, $\gamma_{01}$ to $\gamma_{010}$ represent the between-person associations between a set of predictors and daily sedentary behavior (sedentary behavior*di*), $\gamma_{10}$ to $\gamma_{130}$ represent the average strength of the within-person associations between a set of predictors and daily sedentary behavior, and *u*0*i* and *u*1*i* are individual-level residual deviations that are uncorrelated with the day-level residuals *edi*. Within this particular multilevel model predicting daily sedentary behavior, the variables usual and daily planning and habit strength served to test hypotheses regarding the extended HAPA + habit model whereas usual and daily physical activity, musculoskeletal symptoms, cold and flu symptoms, gastrointestinal symptoms, cardiorespiratory symptoms, day of week, and day in study served as statistical controls to reduce bias in estimates of the coefficients of substantive interest. Separate models were estimated to predict daily self-reported and objectively measured sedentary behavior. Models predicting daily self-reported sedentary behavior will not be discussed in the text but results from these models are presented in the supplementary materials. This same approach was applied to estimate models of daily plans and intentions to limit sedentary behavior. In the multilevel model predicting daily planning, the variables usual and daily intentions and efficacy served to test hypotheses regarding the extended HAPA + habit model whereas usual and daily musculoskeletal symptoms, cold and flu symptoms, gastrointestinal symptoms, cardiorespiratory symptoms, day of week, and day in study served as statistical controls to reduce bias in estimates of the coefficients of substantive interest. In the multilevel model predicting daily intentions, the variables usual and daily efficacy, outcome expectations, risk perceptions, and habit strength served to test hypotheses regarding the extended HAPA + habit model, whereas usual and daily musculoskeletal symptoms, cold and flu symptoms, gastrointestinal symptoms, cardiorespiratory symptoms, day of week, and day in study served as statistical controls to reduce bias in estimates of the coefficients of substantive interest.

## RESULTS

Participants provided self-report data for a total of 1,238 of the 1,300 possible person-days (95% response rate; median = 13 days; *M* = 12.3, *SD* = 1.6). Participants provided valid objectively measured data for a total of 1,195 of the 1,300 possible person-days (92% response rate; median = 12 days; *M* = 11.9, *SD* = 1.5). Of those valid days, participants reported not removing the activity monitor at all on 96% of the days. When the monitor was removed on a valid day, 3% of these removal events lasted more than 10 min but for less than 1 hr. On average, participants provided over 15 valid waking wear time hours of data each day (*M* = 15.6, *SD* = 1.4). Missing data (<1%) was treated as missing completely at random.

Table 1 presents descriptive statistics and between- and within-person correlations between sedentary behavior (self-reported and objectively measured), dual-process constructs, and control variables. Participants reported engaging in more than 10 hr of sitting each day (*M* = 636.6 min). Objective data indicated that participants sat for slightly less than 10 hr each day (*M* = 573.7 minutes). Participants reported moderate levels of task self-efficacy (*M* = 61.9), intentions (*M* = 61.2), and planning (*M* = 43.9) to limit sedentary behavior (on a 0 to 100 scale). Participants reported moderate-to-high levels of outcome expectations for light-intensity physical activity (*M* = 3.2) and sedentary behavior risk perceptions (*M* = 2.8; on a 0 to 4 scale). Additionally,

participants reported moderate levels of sedentary behavior habit strength (*M* = 2.2 on a 0 to 4 scale).

Table 1
*Descriptive Statistics, Correlations, and Intraclass Correlation Coefficients of Sedentary Behavior, Motivational Constructs, and Other Variables*

| | *M* | *SD* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Daily objective sedentary behavior (min/day) | 573.7 | 145.0 | (.55) | .28 | −.31 | −.31 | −.21 | −.52 | −.01 | | | | .01 | −.03 | .01 | .04 |
| 2. Daily self-reported sedentary behavior[a] (min/day) | 636.6 | 219.9 | .38 | (.56) | −.20 | −.24 | −.10 | −.38 | −.31 | | | | .14 | .01 | .01 | .05 |
| 3. Daily intentions to limit sitting time[b] | 61.2 | 27.8 | −.24 | −.18 | (.69) | .83 | .58 | .05 | .24 | | | | −.01 | −.05 | .04 | −.01 |
| 4. Daily efficacy to limit sitting time[b] | 61.9 | 27.1 | −.19 | −.22 | .83 | (.66) | .51 | .08 | .25 | | | | .01 | −.02 | .07 | .01 |
| 5. Daily planning[c] | 43.9 | 31.4 | −.19 | −.11 | .51 | .45 | (.70) | .02 | .22 | | | | −.01 | −.01 | .01 | −.01 |
| 6. Daily objective physical activity (min/day) | 96.0 | 50.4 | −.45 | −.29 | .07 | .09 | .05 | (.42) | −.09 | | | | −.19 | .01 | −.04 | −.11 |
| 7. Daily self-reported physical activity[d] (MET-min/day$^{-1}$) | 617.9 | 612.5 | .09 | .09 | .21 | .20 | .17 | .10 | (.11) | | | | .23 | .10 | .18 | .34 |
| 8. Sedentary behavior risk perception[e] | 2.8 | .9 | .01 | −.07 | .20 | .17 | .17 | .01 | −.12 | | | | | | | |
| 9. Physical activity outcome expectations[f] | 3.2 | .8 | .01 | −.01 | .06 | .04 | .14 | .04 | −.11 | .34 | | | | | | |
| 10. Sedentary behavior habit strength[c] | 2.2 | 1.1 | .22 | .18 | −.21 | −.20 | −.18 | −.24 | .02 | −.14 | −.02 | | | | | |
| 11. Daily musculoskeletal symptoms[g] | 23.6 | 27.8 | −.24 | .01 | −.10 | −.10 | .03 | −.11 | .15 | −.04 | −.01 | .11 | (.66) | .31 | .46 | .49 |
| 12. Daily cold and flu symptoms[g] | 6.1 | 15.5 | −.22 | .01 | −.08 | −.07 | .01 | −.01 | .06 | −.17 | −.16 | .04 | .24 | (.44) | .66 | .57 |
| 13. Daily gastrointestinal symptoms[g] | 5.9 | 14.4 | −.17 | .02 | −.03 | −.01 | .01 | −.03 | .09 | −.06 | −.05 | −.01 | .30 | .43 | (.36) | .55 |
| 14. Daily cardiorespiratory symptoms[g] | 4.7 | 12.2 | −.14 | .02 | −.05 | −.01 | .01 | −.04 | .16 | −.18 | −.09 | .09 | .33 | .37 | .36 | (.38) |

*Note.* Intraclass correlation coefficients representing the proportion of between-person variance appear in parentheses on the diagonal of the correlation matrix. Coefficients below the diagonal represent correlations across days and people (i.e., within-person correlations). Coefficients above the diagonal represent correlations of intraindividual means (i.e., between-person correlations).
[a] Composite score derived from 9-item scale. [b] Composite score derived from 2-item scale. [c] Composite score derived from 4-item scale. [d] Composite score derived from 3-item scale. [e] Composite score derived from 8-item scale. [f] Composite score derived from 7-item scale. [g] Single item.

Table 1 also presents two different types of bivariate correlations. The first type is the between-person correlations (i.e., correlations between each person's average rating of variables over the course of the study; above diagonal). The second type is the within-person correlations (i.e., correlations between each day's rating of variables; below diagonal). Between- and within-person correlations exhibited similar patterns. Self-reported and objectively measured sedentary behavior were moderately correlated (*r*s = .38, .28). Sedentary behavior (self-reported and objectively measured) had weak-to-moderate positive correlations with habit strength (*r*s = .22, .18) and weak-to-moderate negative correlations with planning (*r*s = −.10, −.21). Planning had moderate positive correlations with intentions (*r*s = .51, .58). Intentions had strong positive correlations with task self-efficacy (*r*s = .83, .83). Intentions also had weak-to-moderate positive correlations with sedentary behavior risk perceptions and light-intensity physical activity outcome expectations (*r*s = .20, .06, respectively) at the between-person level. Intraclass correlation coefficients (ICC) were calculated to describe the proportion of variance in each variable attributable to between-person differences. ICCs indicated that approximately half of the variance in self-reported and objectively measured sedentary behavior and two thirds of the variance in task self-efficacy, intentions, and planning was the between-person variance, with the remainder driven by within-person factors and measurement error.

## Multilevel Model of Daily Sedentary Behavior

There were no differences in objectively monitored sedentary behavior between participants who tended to form stronger or weaker plans ($\gamma_{01} = -0.41$, $p = .24$) but, as hypothesized, participants were less sedentary on days when they formed stronger-than-usual plans to limit sedentary behavior ($\gamma_{10} = -0.51$, $p = .005$). Also as hypothesized, sedentary behavior habit strength was positively associated with daily sedentary behavior (monitored behavior: $\gamma_{02} = 19.97$, $p = .04$).

Both usual ($\gamma_{03} = -1.44$, $p = .001$) and daily physical activity ($\gamma_{20} = -1.13$, $p = .001$) were associated with less objectively measured sedentary behavior. Men engaged in more daily sedentary behavior than women ($\gamma_{08} = 57.13$, $p = .006$) and participants were more sedentary on Wednesdays and Thursdays than on Saturdays ($\gamma 100 = 22.54$; $p = .04$; $\gamma_{110} = 30.48$; $p = .004$). Objectively monitored sedentary behavior did not differ as a function of any physical symptoms, age, BMI, day-of-week, or exposure to study procedures.

As indicated by the pseudo-$R^2$, this model accounted for 14% of the variance in objectively measured sedentary behavior, with habit strength accounting for 9% and daily planning accounting for 5% of the explained variance. These results are replicated in a model predicting self-reported sedentary behavior; coefficients from that model are available in the supplementary materials.

## Multilevel Model of Daily Plans to Limit Sedentary Behavior

As hypothesized, plans to limit sedentary behavior were stronger (a) for participants with stronger usual intentions to limit sedentary behavior ($\gamma_{02} = 1.17$, $p = .001$) and (b) on days when participants had higher-than-usual intentions to limit sedentary behavior ($\gamma_{20} = 0.20$, $p = .004$). Our hypotheses about task self-efficacy received mixed support. Daily plans to limit sedentary behavior were stronger (a) for people with weaker usual self-efficacy ($\gamma_{01} = -0.59$, $p = .04$), and (b) on days when they had higher-than-usual self-efficacy ($\gamma_{10} = 0.14$, $p = .001$). Plans tended to be weaker for older participants ($\gamma_{08} = -0.70$, $p = .01$) and as exposure to the protocol increased ($\gamma_{013} = -0.40$, $p = .001$). No other covariates were significantly associated with plans to limit sedentary behavior.

As indicated by the pseudo-$R^2$, this model accounted for approximately 20% of the variance in daily plans to limit sedentary behavior. Daily intentions accounted for 23%, daily task self-efficacy accounted for 10%, and usual intentions and task self-efficacy each accounted for 2% of the explained variance.

## Multilevel Model of Intentions to Limit Sedentary Behavior

As hypothesized, intentions to limit sedentary behavior were stronger (a) for participants with greater usual task self-efficacy for limiting sedentary behavior ($\gamma_{01} = 0.96$, $p = .001$), and (b) on days when task self-efficacy was higher than usual ($\gamma_{10} = 0.61$, $p = .001$). Contrary to our hypotheses, intentions to limit sedentary behavior were not associated with outcome expectancies for light-intensity physical activity, risk perceptions for sedentary behavior, or habit strength for sedentary behavior (*p*s = .89, .49, .62, respectively). Regarding covariates,

participants formed stronger intentions to limit sedentary behavior as their exposure to the study protocol increased ($\gamma_{012} = 0.19$, $p = .007$). Intentions were not associated with any other covariates. As indicated by the pseudo-$R^2$, this model accounted for approximately 44% of the variance in daily intentions to limit sedentary behavior, with daily task self-efficacy accounting for 80% and usual task self-efficacy accounting for 4% of the explained variance.

## DISCUSSION

This study provided the first test of a dual-process (HAPA + habit) model of sedentary behavior in older adults. The bottom panel of Figure 1 summarizes the significant relations in the HAPA + habit model that was tested. Overall, older adults in this study sat for approximately 60% of their waking hours each day. These findings are similar to National Health and Nutrition Examination Survey data which used accelerometer-derived sitting time (Matthews et al., 2008). Although self-reports are generally expected to underestimate sedentary behavior because of a lack of awareness of the behavior, self-reported sedentary time was greater than objectively measured sedentary time by approximately one hour. Because participants spent the majority of their day sitting, on average, it may be difficult for participants to accurately recall time spent sitting. Participants may lose track of time while sitting for extended periods and therefore grossly overestimate time engaged in sedentary activities. Greater self-report estimates may also be a product of the domain-specific measure used in this study (Conroy, Maher, et al., 2013; Kremers & Brug, 2008; Kremers, van der Horst, & Brug, 2007). Although, participants were given instructions not to double count time (e.g., counting time spent sitting while driving in a car and chatting with friends as time spent driving or socializing, but not both), it is possible that this task is more challenging than expected in practice. Also, if older adults are experiencing any executive functioning decline, those cognitive changes may make it difficult to accurately recall and assign sedentary behavior that occurs in multiple domains to one domain without double counting (Salthouse, Atkinson, & Berish, 2003). It is unlikely that the underestimation of objective and overestimation of self-reported sedentary behavior is the result of the ActivPAL activity monitor misclassifying light-intensity physical activity such as standing. In laboratory tests, the ActivPAL was found to be 100% accurate in measuring sitting, standing, and moving time compared to direct observation and in free-living experiments the ActivPAL has been shown to overestimate time spent sitting by 2.8% compared to direct observation (Grant et al., 2006; Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011; Ryan, Grant, Tigbe, & Granat, 2006). The ActivPAL appears to be a more precise and sensitive measure of sitting time compared to the Actigraph GT3X, a common objective-measure of sedentary behavior (Kozey-Keadle et al., 2011).

A major finding was that habit strength for sedentary behavior—an automatic motivational process—positively predicted objectively monitored sedentary behavior in older adults, just as it did in previous research with college students (Conroy, Maher, et al., 2013). Habits regulate much of our daily lives (Wood, Quinn, & Kashy, 2002), so it was not surprising that the association between habit strength and sedentary behavior appears to be robust for young and older adults. If there was a surprise, it was only that habits did not have a larger association with sedentary behavior given that older adults have had more time to develop associations between cues in the environment and a behavioral response (Aarts et al., 1997; Verplanken et al., 2008). Habit strength, however, did have the largest pseudo-$R^2$ of all the predictors of behavior, again

emphasizing that automatic processes, particularly habits, represent a crucial part of, and should be incorporated into, theoretical frameworks attempting to explain and predict understanding health behaviors. From this study it is impossible to determine the types of cues that lead older adults' sedentary schemas to be activated. Future research should focus on identifying these cues as it will likely inform interventions focused on disrupting habits for sitting and creating new habits for alternative health behaviors such as walking. Additionally, it is possible that habits can be disrupted without planning or intending to do so. For example, constraints of the built environment (e.g., limited or uncomfortable seating options) may influence health behaviors regardless of intrapersonal motivational processes. Extending research to multilevel influences on sedentary behavior will likely lead to the more comprehensive, effective interventions.

A second key finding was that plans to limit sedentary behavior—a controlled motivational process—were a proximal predictor of sedentary behavior at the within-person, but not between-person, level of analysis. This is the first evidence that directly links planning with sedentary behavior. With other behaviors, planning has proven to be critical for bridging the intention-behavior gap, breaking old habits and creating new habits (Carraro & Gaudreau, 2013; Gollwitzer & Sheeran, 2006; Webb, Sheeran, & Luszczynska, 2009). Planning context-specific substitutes for sedentary behavior may be a promising approach for overcoming strong sedentary habits. An interesting nuance in this finding was that daily, but not usual, plans are associated with sedentary behavior. Considering that planning and other controlled motivational constructs observed in this study varied significantly from day to day, interventions may benefit from sensitivity to this daily motivational variation by targeting plan formation on days with the greatest need to reduce sedentary behavior. Although the effect size of the pseudo-$R^2$ for planning on sedentary behavior (pseudo-$R^2$ = .04) was smaller than effects seen in previous research (Carraro & Gaudreau, 2013), it should be noted that because of the dynamic nature of these associations small effects can accumulate over time, perhaps resulting in clinically meaningful effects. Future interventions employing planning as an intervention component should consider how these plans are framed. In a daily action planning intervention with a sample of college students, action plans to limit sedentary behavior were not associated with changes in sedentary behavior (Maher & Conroy, 2015). Effective action plans may result from focusing on promotion (e.g., plans to walk) rather than prevention (e.g., plans to limit sedentary behavior). Future research should also compare the extent to which plans for different behavioral substitutes (e.g., standing vs. walking) are effective for reducing sedentary behavior and evaluate whether planning interventions are effective for reducing habit strength for sitting.

Interestingly associations between usual physical activity and sedentary behavior differed by the measure of behavior used. Findings from the model using objective data revealed that people who engaged in more sedentary behavior, on average, tended to engage in less physical activity; however, findings from the model using self-reported data revealed that people who engaged in more sedentary behavior, on average, tended to engage in more physical activity. The objective measure of physical activity focused on duration of activity (i.e., time spent stepping) while the self-reported measure used information about duration and intensity of activity to calculate the volume of energy expended (i.e., METs/day). This suggests that differences in these associations may be attributable to the different conceptualizations of physical activity. It may be that older adults who engage in higher intensity physical activity, on average, also tend to spend more time sitting to recuperate and rest after intense physical activity, resulting in a positive association

between usual physical activity and sedentary behavior. Whereas with objective data only duration is considered and, as a result, greater time spent engaging in physical activity, on average, is associated with less time spent sitting.

A third key finding from this study was that older adults' planning to limit sedentary behavior had its motivational roots in daily task self-efficacy and usual and daily intentions to limit sedentary behavior. Interestingly, usual task-self efficacy was negatively associated with planning. Older adults who, on average, strongly believed they could limit their sedentary behavior were less likely to plan how to limit their behavior. This finding may reflect overconfidence or that they have strong automatic processes in place to limit sedentary behavior and obviate the need for planning. This finding was unexpected so it warrants replication in future work.

Intentions to limit sedentary behavior were associated with both usual and daily task self-efficacy. This finding extended previous qualitative reports that efficacy beliefs are determinants of sitting time in older women (Chastin et al., 2014). These findings reinforce the potential value of daily boosters for task-self-efficacy to support intention formation and planning processes as a part of interventions to reduce sedentary behavior in older adults. Older adults may have particularly low levels of task self-efficacy to limit sedentary behavior due to pain or functional limitations, aging stereotypes, and previous failed attempts to engage in physical activity (Greenwood-Hickman et al., 2015; Sparling, Howard, Dunstan, & Owen, 2015). Efficacy beliefs can be developed by (a) providing mastery experiences where older adults engage in taking short breaks from sitting, or (b) modeling where older adults learn from similar others who have been successful in limiting or interrupting their sitting time. (Bandura, 1997).

The HAPA model derives from social-cognitive theory and posits that intentions are formed when people expect desirable outcomes from a behavior or increased risk from failing to engage in a behavior (Schwarzer et al., 2007). In this study, neither outcome expectancies for light-intensity physical activity nor risk awareness for sedentary behavior were linked with older adults' intentions to reduce their sedentary behavior. Although epidemiological research has established the health risks of excessive sedentary behavior in recent years, these findings may have had limited uptake beyond the scientific community. As public health messaging broadens to focus on reducing sedentary behavior as well as promoting moderate-vigorous physical activity, awareness of the benefits of light physical activity or the dangers of excessive sedentary time may be more likely to move the needle on intention formation. This question warrants closer attention in future research, particularly with interventions that include educational components to heighten awareness about outcomes and risks.

Returning to the role of habit, it was somewhat surprising that habit strength did not predict intention formation. Ordinarily, habits serve as a window into a person's behavioral intentions (Wood & Neal, 2007). In this case, it appears that counterhabitual intentions (i.e., to limit sedentary time) may be independent of habit strength for sedentary behavior. This finding is encouraging because habit strength will not interfere with efforts to promote the controlled motivational processes that are useful for initiating behavior change.

Both sedentary behavior and motivational processes varied from day to day in older adults; however, only associations between day of week and objectively measured sedentary behavior were documented. These results suggest that older adults engaged in more sedentary behavior on weekdays than on weekend days, which is consistent with previous research in college students and older adults (Conroy, Maher, et al., 2013; Marshall et al., 2014). The majority of older adults participating in this study were retired. Although older adults may not face work-related barriers to limiting sedentary behavior, the social calendar likely creates daily barriers to limiting sedentary behavior. Therefore, interventions designed to reduce older adults' sedentary behavior may benefit from targeting sedentary social activities that older adults engage in on weekdays.

Finally, results from this study and others emphasize the dynamic nature of motivational constructs and suggest that popular theories of motivation which rely solely on time-invariant, between-person factors may be missing important motivational processes that unfold naturally within the context of daily life (Conroy, Elavsky, Doerksen, & Maher, 2013; Conroy et al., 2011; Conroy, Maher, et al., 2013). Factors explaining interindividual variation in a population may not accurately reflect individual-level processes and thus may explain the limited explanatory power of our current theories of motivation (e.g., McEachan, Conner, Taylor, & Lawton, 2011). Although more work is needed to validate findings regarding within-person motivational process, the best way to establish their validity is to incorporate these time-varying constructs within popular theoretical frameworks and formally evaluate their predictive power.

With respect to limitations, the present sample was homogeneous with respect to race and ethnicity. On average, non-Hispanic Black and Mexican American older adults exhibit high rates of sitting (9.0 and 8.3 hr/day, respectively) and it is not clear if these findings will generalize to those populations (Matthews et al., 2008). This study was powered to detect medium-sized between-person associations. Therefore, it is possible that this study was slightly underpowered to detect some between-person differences (e.g., associations between outcome expectancies and intentions). Future research, powered to detect small between- and within-person associations is needed. Participants reported on a limited range of motivational characteristics. Others, such as perceived barriers and resources or maintenance and recovery self-efficacy, may also be relevant for the initiation and maintenance of sedentary behavior change. This study also assessed habit strength using a self-reported measure, which is somewhat controversial yet the current standard for assessing habit strength (Gardner et al., 2012; Sniehotta & Presseau, 2012). Other automatic processes may also play a role in regulating behavior and should be considered in future research (e.g., automatic evaluations of sitting or light-intensity physical activity). In addition, there are many plausible third variables that could contribute to older adults' sedentary behavior and should, therefore, be accounted for in future research. These include, but are not limited to, sleep quality, stress, medical conditions, and number of medications. Finally, the study design was nonexperimental so it is not possible to draw strong causal conclusions from these data.

In conclusion, this study demonstrated that older adults' daily sedentary behavior changes over time and those changes in behavior are coupled with changes in motivation. The extended HAPA + habit model showed that both controlled and automatic processes are associated with older adults' sedentary behavior. These findings speak to the value of conceptualizing sedentary behavior motivation through the lens of a dual-process theory. Based on the present study, suitable motivational targets for interventions to reduce sedentary behavior include intentions, plans, and

task self-efficacy for limiting sedentary behavior and habit strength for sitting. Interventions targeting these mechanisms in older adults are needed in our graying society, given the accumulating evidence the adverse health consequences of excessive sedentary behavior.

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