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THE DYNAMICS OF DAILY SEDENTARY BEHAVIOR IN OLDER ADULTS

A Dissertation in

Kinesiology

by

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Abstract

Sedentary behavior has emerged as a major public health threat because accumulating evidence links excessive sitting with deleterious health consequences, independent of physical activity. On average, older adults spend more than 60% of their waking hours each day sitting – the most out of any segment of the population. Understanding the factors that contribute to this high volume health behavior and its consequences will facilitate the development of effective interventions to reduce sedentary time that also promote healthy and successful aging. This dissertation aims to (1) identify the motivational processes that contribute to sedentary behavior, (2) test relations between sedentary behavior and life satisfaction – an important indicator of well-being and successful aging in older adults, and (3) evaluate the feasibility, acceptability, safety, and preliminary efficacy of a brief psychoeducational intervention designed to reduce older adults’ sedentary behavior. A 14-day ecological momentary assessment study with ambulatory monitoring was conducted to capture time-varying and time-invariant motivation, behavior, and evaluations among older adults (n = 100). These data were used to test hypotheses about the motivational antecedents of daily sedentary behavior and hypotheses about relations between daily sedentary behavior and life satisfaction. Next, a brief psychoeducational intervention to reduce older adults’ sedentary behavior was developed and implemented at local senior centers (n = 5). This intervention was evaluated in terms of feasibility, acceptability, safety, and preliminary efficacy. Results of these studies led to five major conclusions. First, older adults’ sedentary behavior is regulated by both controlled and automatic motivational processes. Second, both between-person and within-person motivational processes were associated with sedentary behavior. Third, sedentary behavior and life satisfaction were negatively linked through within-person processes. Fourth, older adults found the psychoeducational intervention approach to be engaging. Finally, the intervention reduced older
adults’ self-reported weekday sedentary behavior by approximately two hours more per day compared to the control group. Ultimately, this dissertation informs the development of interventions designed to reduce older adults’ sedentary behavior to promote healthy and successful aging. Prioritizing healthy aging interventions of this nature may reduce health care costs associated with treatment and management of chronic diseases and improve care for older adults.
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Chapter I: Introduction
The number of American older adults, or adults age 65 and older, is expected to almost double by the middle of this century (Centers for Disease Control and Prevention, 2013). At that point, older adults will make up more than one-fifth of the nation’s population (compared to less than 10% in 1970). By 2050, 83.7 million Americans will be age 65 or older, compared with 43.1 million in 2012.

One reason for the graying of America can be attributed to the fact that people are living longer. In 1972, Americans who were 65 years old could expect to live for approximately 15 more years and in 2010 they could expect to live approximately 19 more years (Centers for Disease Control and Prevention, 2013). This shift in the population has led to an increased focus on making sure the additional years added to people’s lives are quality years (Rowe & Kahn, 1997; Pruchno, 2015). Therefore, it is not surprising that healthy aging interventions have been developed to modify people’s health behaviors as a way to promote quality of life in older age.

Increasing older adults’ physical activity has long been viewed as a way to promote healthy aging. Engaging in regular physical activity can reduce risk for chronic conditions, delay or even prevent the onset of disability, and enhance well-being and quality of life (Physical Activity Guidelines Advisory Committee, 2008). Yet it is estimated that fewer than 3% of older adults attain sufficient levels of physical activity to meet public health recommendations (i.e., 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity physical activity per week) and experience the subsequent health benefits (Troiano et al., 2008). Older adults face many barriers to engaging in recommended levels of physical activity including inexperience with intense physical effort, aging stereotypes, fatigue, soreness and pain associated with engaging in moderate- to vigorous-intensity physical activity, risk of injury and medical
complications, limited availability of facilities and specialized equipment, and costs of classes and coaching (Brawley, Rejeski, & King, 2003; Lunt et al., 2014).

Even if older adults cannot attain recommended levels of physical activity, they can still attain some health benefits. A recent review concluded that health benefits begin with any increase above the very lowest levels of activity; the greatest health and functional benefits are found for increments in activity within the lower end of the overall spectrum, where adults are not achieving the mainstream moderate intensity prescription (Powell, Paluch, & Blair, 2011). This finding is consistent with the oft-overlooked principle underlying the national physical activity guidelines – doing something is better than doing nothing (Physical Activity Guidelines Advisory Committee, 2008).

One way that older adults can increase physical activity throughout the day is by displacing sedentary behavior with bouts of light-intensity physical activity such as standing or slow walking (Smith, Ekelund, & Hamer, 2015; Sparling, Howard, Dunstan, & Owen, 2015). Although definitions of sedentary behavior can vary, recent conceptualizations of sedentary behavior include two crucial elements. Specifically, sedentary behavior is defined as any waking activity that (1) occurs in a seated or reclined position and (2) expends little energy (≤1.5 metabolic equivalents; Boyington, Joseph, Fielding, & Pate, 2014; Gibbs, Hergenroeder, Katzmarzyk, Lee, & Jakicic, 2014; Sedentary Behavior Research Network, 2012). Objective measures of sedentary behavior indicate that older adults spend nearly nine and a half waking hours sitting each day (Harvey, Chastin, & Skelton, 2014; Matthews et al., 2008). Older adults represent the segment of the population that sits the most.

Excessive sedentary behavior significantly increases older adults’ risk for negative health consequences. Excessive sedentary behavior has been linked with increased risk for all-cause
mortality, non-communicable diseases such as cardiovascular disease and type II diabetes, as well as poor physical and cognitive functioning and well-being in older adults – all of which have implications for successful aging in older adults (Biswas et al., 2015; de Rezende, Rey-López, Matsudo, & do Carmo Luiz, 2014; Dogra & Stathokostas, 2012; Gennuso, Gangnon, Matthews, Thraen-Borowski, & Colbert, 2013; Hamer & Stamatakis, 2013). Furthermore, these health risks are independent of older adults’ physical activity suggesting that sedentary behavior is an important health behavior in and of itself to modify.

Given this, it is not surprising that increasing numbers of interventions are being developed to displace older adults’ sedentary behavior with light-intensity physical activity. While these interventions have had modest success in reducing older adults’ sedentary behavior (Chang, Fritschi, & Kim, 2013; Fitzsimons et al., 2013; Gardiner, Eakin, Healy, & Owen, 2011; King et al., 2013), the success of future interventions likely hinges on gaining a better understanding of the motivational antecedents that lead to sedentary behavior.

Dual-process theories of motivation may be helpful in explaining older adults’ sedentary behavior. Dual-process theories posit that both controlled and automatic processes regulate our behavior (Hofmann, Friese, & Wiers, 2008; Smith & DeCoster, 2000). Controlled processes are conscious, effortful, slow, and volitional and include constructs outlined in social-cognitive theories of motivation (e.g., intentions, efficacy beliefs, attitudes). Automatic processes are nonconscious, effortless, fast, and unintended and can include constructs like habits. A common automatic motivational process, habit strength, develops through the repeated pairing of a contextual cue within the environment and a behavioral response so that, over time, encountering the cue automatically elicits the behavioral response (Aarts, Paulussen, & Schaalma, 1997). This
study will be the first to apply this theoretical framework to understand the motivational processes that regulate sedentary behavior in older adults.

Moreover, understanding how sedentary behavior impacts aspects of well-being, such as life satisfaction, can shed light on whether interventions to reduce sedentary behavior can promote healthy and successful aging in older adults. It is currently unclear to what extent older adults’ sedentary behavior needs to change to have a meaningful impact on aspects of successful aging. Understanding how sedentary behavior is related to life satisfaction – an important indicator of well-being and successful aging in older adults – will aide future interventions in developing target behavioral goals.

In addition to understanding the motivational antecedents and psychological consequences of sedentary behavior, developing effective interventions also involves identifying an optimal mode for delivering intervention content. Existing interventions designed to reduce sedentary behavior in older adults typically involve face-to-face counseling; however, such an approach is expensive and limits the ability to disseminate an intervention to the population at large (Dunn, Andersen, & Jakicic, 1998). Broad dissemination and implementation may be easier if interventions do not require highly specialized training for people to deliver them. Efforts to develop standardized materials that can complement group discussions are promising. It is unclear whether older adults would be receptive to an intervention that delivers standard content via video and pairs those video segments with group discussions.

This dissertation uses a two-step approach to addressing these critical gaps in the literature. First, a 14-day ecological momentary assessment with ambulatory monitoring was conducted to capture time-varying and time-invariant motivation, behavior, and evaluations among older adults. Second, a brief psychoeducational intervention to reduce older adults’
sedentary behavior was developed and implemented at local senior centers. This intervention was assessed in terms of feasibility, acceptability, safety, and preliminary efficacy. Ultimately, this dissertation has three specific aims to address critical gaps in the literature:

1. to identify the time-varying and time-invariant controlled and automatic motivational processes that contribute to sedentary behavior,

2. to identify the time-varying and time-invariant associations between sedentary behavior (both self-reported and objectively-measured) and life satisfaction – an indicator of psychological well-being and successful aging in older adults, and

3. to evaluate the feasibility, acceptability, safety, and preliminary efficacy of a brief psychoeducational intervention designed to reduce sedentary behavior by modifying the controlled and automatic processes that regulate older adults’ sedentary behavior.

Taken as a whole, this dissertation was designed to (a) establish the time-varying and time-invariant controlled and automatic motivational processes that regulate sedentary behavior in older adults and will identify suitable self-regulatory targets for intervention, (b) determine whether life satisfaction, an indicator of successful aging, is regulated by sedentary behavior independent of physical activity, and (c) determine whether a brief psychoeducational intervention format can engage older adults and possibly reduce their sedentary behavior. The results from this dissertation can close gaps within the literature surrounding older adults’ sedentary behavior and accelerate progress in developing interventions to reduce sedentary behavior. Reducing sedentary behavior in older adults has the potential to improve health profiles, reduce risk for premature mortality and non-communicable diseases (e.g., cardiovascular disease, type II diabetes), delay or eliminate the onset of physical or cognitive
disabilities and improve well-being. Given the graying of our society and the unsustainable increases in preventable health care costs, healthy aging interventions of this nature are needed.
References


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Chapter II: A Dual-Process Model of Older Adults’ Sedentary Behavior
Abstract

Older adults engage in the greatest amount of sedentary behavior yet little is known about the factors that motivate them to sit so much. 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. Over the course of the study 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. Multilevel models predicting behavior revealed that (1) self-reported and objectively-measured sedentary behavior were negatively associated with planning at the within-, but not the between-person level, and (2) self-reported and objectively-measured sedentary behavior were positively associated with sedentary behavior habit strength. Multilevel models predicting plans to limit sedentary behavior revealed that (1) planning was positively associated with task self-efficacy at the within-person level, but negatively associated at the between-person level, and (2) planning was positively associated with intentions at the between- and within-person level. Multilevel models predicting intentions to limit sedentary behavior revealed that (1) intentions were positively associated with task self-efficacy at the between and within-person level, but (2) intentions were not associated with light-intensity physical activity outcome expectations, sedentary behavior risk perceptions, or sedentary behavior habit strength. 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.
A Dual-Process Model of Older Adults’ Sedentary Behavior

Excessive sedentary behavior, or time spent sitting, has been linked with increased risk for all-cause mortality, non-communicable diseases as well as poor physical and cognitive functioning and well-being in older adults independent of physical activity (Biswas et al., 2015; de Rezende et al., 2014). Older adults are particularly susceptible to these adverse health outcomes because older adults sit more than any other segment of the population. Older adults, on average, sit for more than 9 waking hours per day (Harvey et al., 2014; Matthews et al., 2008).

Not surprisingly, there have been attempts to reduce older adults’ sedentary behavior (Chang et al., 2013; Fitzsimons et al., 2013; Gardiner, Eakin, et al., 2011; King et al., 2013); however, these interventions have largely focused on enhancing controlled processes previously associated with physical activity. Given that sedentary behavior and physical activity are independent health behaviors with independent health consequences, the processes that regulate sedentary behavior may differ from those that regulate physical activity. This study extends previous work by examining older adults’ sedentary behavior through a dual-process lens which considers both the controlled and automatic processes that regulate behavior. This manuscript presents a 14-day daily diary study of older adults designed to test hypotheses from a dual-process theory of motivation applied to sedentary behavior.

Motivation Underlying Sedentary Behavior

Dual-process theories of motivation posit that both controlled and automatic processes regulate our behavior (Hofmann, Friese, & Wiers, 2008; Smith & DeCoste, 2000). Controlled processes are conscious, effortful, slow, and volitional and include constructs outlined in social-cognitive theories of motivation (e.g., intentions, efficacy beliefs, attitudes). Automatic processes
are nonconscious, effortless, fast, and unintended and can include constructs like habits. Habits develop through the repeated pairing of a contextual cue within the environment and a behavioral response so that, over time, encountering the cue automatically elicits the behavioral response (Aarts, Paulussen, & Schaalma, 1997). It is likely that both controlled and automatic motivational processes exert an influence on older adults’ sedentary behavior.

Evidence of the regulation of sedentary behavior via dual-processes exists in college students. Conroy and colleagues examined the role habit strength as well as the time-varying and time-invariant influence that intentions play as automatic and controlled process regulating sedentary behavior, respectively (Conroy, Maher, Elavsky, Hyde, & Doerksen, 2013). Conroy et al. found that both sedentary behavior and intentions to limit sedentary behavior varied within people over time and both intentions to limit sedentary behavior (at both the between- and within-person level) and habit strength were significant predictors of behavior. These results were consistent with proposals that dual-process models add explanatory power when studying health behaviors (Sheeran, Gollwitzer, & Bargh, 2013).

Figure 1 illustrates a proposed dual-process model to explain older adults’ sedentary 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 (Aarts et al., 1997; Verplanken, Walker, Davis, & Jurasek, 2008). Strong habits to engage in sedentary behavior are likely to initiate a behavioral response automatically and effortlessly within a person unless the person intervenes by exerting self-control to pursue a counter-habitual goal. Although sedentary habits have not been investigated in older adults, qualitative work indicates that older adults believe
that controlled processes, such as self-efficacy for limiting sedentary behavior, are determinants of their behavior as well (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 not only outlines the processes that lead to intention formation, but also the processes that allow for intentions to be translated into behavior (thus overriding habitual behaviors; Schwarzer et al., 2007a).

HAPA, like other social-cognitive theories, posits that intention formation is regulated by three common motivational constructs: task self-efficacy, outcome expectations, and risk perceptions. Task self-efficacy refers to the extent to which an individual believes they can successfully complete a particular behavior. Outcome expectations refer to the extent to which a person believes engaging in a particular behavior can result in a desired outcome. Risk perceptions refer to the extent to which a person believes engaging in a particular behavior can result in an undesired outcome. Additionally, work on the habit-goal interface suggests that intentions may be inferred from habits (Wood & Neal, 2007). Intentions can be derived from past behavior and behavior can be regulated by habits. 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), 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. *Coping planning* involves identifying how one will overcome obstacles that could interfere with the goal striving process. In addition to intentions influencing planning, HAPA proposed the task self-efficacy influences planning. Applying this extended version of HAPA to sedentary behavior will provide the most complete dual-process model to date of the processes influencing sedentary behavior.¹

**Distinguishing Time-Varying and Time-Invariant Motivational Processes**

Daily obligations and constraints as well as the social calendar can result in daily changes in sedentary behavior (Conroy, Maher, et al., 2013; Kozey-Keadle, Libertine, Staudenmayer, & Freedson, 2012). In addition to day to day changes in behavior, the motivational constructs that regulate behavior are likely to change from day to day. For example, Conroy et al. (2013) found that daily changes in intentions to limit sedentary behavior predicted changes in daily sedentary behavior.

Although there is limited work documenting the time-varying nature of motivation in older adults, there is evidence that older adults face unique constraints in daily life that influence their activity (or inactivity) patterns (e.g., poor health, frailty, lack of energy, time constraints; Mannell & Zuzanek, 1991). Therefore, when investigating the processes that regulate sedentary behavior, 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; however, this study is not focused on initiating behavior change so these constructs will not be discussed further.

¹ Other volitional processes that contribute to the translation of intentions into 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; however, this study is not focused on initiating behavior change so these constructs will not be discussed further.
behavior in older adults both the time-invariant processes (i.e., differentiating people who engage in more vs. less sedentary behavior overall) and the time varying processes (i.e., differentiating days when people engage in more vs. less sedentary behavior) should be considered.

Considering previous findings as well as information regarding the unique challenges faced by older adults, daily intentions, task self-efficacy, and plans to limit sedentary behavior and behavior are likely to vary within older adults over time (Conroy, Elavsky, Doerksen, & Maher, 2013; Conroy, Elavsky, Hyde, & Doerksen, 2011). Therefore, the examination of both between- and within-person associations between task self-efficacy, intentions, and plans to limit sedentary behavior and sedentary behavior is warranted. 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). Therefore light-intensity physical activity outcome expectations, sedentary behavior risk perceptions, and sedentary behavior habit strength should be considered time-invariant. This study will be the first application of a dual-process model that considers the time-varying processes underlying 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 techniques was conducted. When predicting sedentary behavior, it was hypothesized that sedentary behavior (a) would be negatively associated with daily plans to limit sedentary behavior, and (b) would be negatively associated with usual plans to limit sedentary behavior and (c) would be positively associated with habit strength. When predicting plans to limit sedentary behavior, it was hypothesized that planning (a) would be positively associated with daily intentions and daily task self-efficacy to limit sedentary behavior and (b)
would be positively associated with usual intentions and usual task self-efficacy to limit sedentary behavior. When predicting intentions to limit sedentary behavior, it was hypothesized that intentions (a) would be positively associated with daily task self-efficacy to limit sedentary behavior, (b) would be positively associated with outcome expectations for light-intensity physical activity and usual task-self-efficacy, and (c) would be negatively associated with risk perceptions for sedentary behavior and habit strength. In testing these hypotheses we controlled for potential time-varying confounds including daily physical symptoms, the day-of-week, and time-in-study and potential time-invariant confounds such as usual physical symptoms, age, sex, and body mass index (BMI). Additionally, in the models predicting daily sedentary behavior we controlled for usual and daily physical activity.

Methods

Participants

One hundred and fourteen community-dwelling older adults expressed an interest in participating in the study. Prospective participants were screened for eligibility. Inclusion criteria were as follows: (a) ages 60 and older and (b) sitting an average of ≥8 hours/day. Participants were excluded if they (a) had been diagnosed by a physician as having dementia or Alzheimer's Disease or (b) 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). Participant flow is documented in Figure 2. Of those 114 participants, 5 participants were ineligible because they reported sitting for <8 hours/day, on average. Eligible participants (n = 109) were scheduled to attend an initial session. Of those participants, 7 participants canceled their initial lab session appointment and declined to reschedule. Participant burden (n = 3) and family-related health issues (n = 3) were cited as the primary reasons for cancelling the
appointment (unknown reason: n = 1). One participant dropped out of the study the same day as their initial training session due to the perceived burden of the protocol. Finally, one participant's tablet data was lost due to a tablet malfunction. Those two participants were excluded from analyses, resulting in a final sample of 67 women and 33 men for data analysis. Almost the entire sample reported that they were White (99%) and non-Hispanic (99%). The mean age of the sample was 74.2 years (SD = 8.2; Range: 60-89 years). Based on World Health Organization cutoffs for BMI, participants were relatively evenly split between normal weight, overweight, and obese (M = 27.3, SD = 5.3; 38.6%, 36.7%, 23.7%, respectively).

Procedures

This study lasted a total of 14 days. At the outset of the study, participants attended an initial session where they were familiarized with the study procedures and equipment to be used in the study. Participants then provided written informed consent. Next, participants were assigned a tablet computer and an ActivPAL3™ activity monitor. Participants were then trained on how to use the tablet to complete questionnaires at the beginning and end of each day and how to affix the activity monitor to their front of their thigh (3-4 inches above the knee). Finally, participants completed a questionnaire to provide information on demographic characteristics and motivation. Over the course of the next 14 days participants completed questionnaires on their tablet and wore the activity monitor 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 the monitor would be submerged under water (i.e., bathing, showering). On Day 7 participants returned to the lab to exchange their activity monitor. On Day 14 participants returned the equipment used in the study. The study procedures outlined above were approved by the local institutional review board.
Measures

Demographic information as well as light-intensity physical activity outcome expectations, sedentary behavior risk perceptions, and sedentary behavior habit strength were assessed at the initial lab visit. Daily task self-efficacy, intentions, and planning to limit sedentary behavior were assessed at the beginning of each day. These daily measures of motivation used 8 waking hours per day of sedentary behavior as the reference point. This reference point was chosen due to epidemiological evidence that health risks associated with sedentary behavior become elevated at levels of sedentary behavior above 8 hours per day (Biswas et al., 2015; de Rezende et al., 2014). Daily self-reported sedentary behavior and physical activity were assessed at the end of each day. Daily objectively-measured sedentary behavior and physical activity were assessed via ActivPAL3™ activity monitors.

Demographics. Demographic information included age, sex, race, ethnicity, and self-reported height and weight.

Sedentary behavior. Daily self-reported sedentary behavior was assessed using a 9-item scale which features domain-specific sedentary activities which are commonly included in other validated measures of sedentary in adults and older adults (Gardiner, Clark, et al., 2011; Visser & Koster, 2013). Items were modified to reflect daily sedentary time rather than weekly to reduce the threat of retrospective bias and recall errors (Matthews, Moore, George, Sampson, & Bowles, 2012). Participants reported the time they spent sitting in each activity that day (i.e., watching TV, using the computer, reading, socializing with friends, in transit, completing hobbies, doing paperwork, eating, or any other activities). Responses to these nine items are then summed each day to create a daily sedentary behavior value. ActivPAL3™ activity monitors (Physical Activity Technologies, Glasgow, Scotland) were used to objectively measure sedentary
behavior and have been validated in older adults (Grant, Dall, Mitchell, & Granat, 2008). The ActivPAL3™ monitor uses an inclinometer and accelerometer to measure posture and activity, respectively, and then classifies that data into periods spent sitting or lying, standing and stepping. Previous research comparing objective measures of sedentary behavior (i.e., ActivPAL3™, Actigraph GT3X™) to direct observation found that the ActivPAL3™ monitor was more precise in measuring sedentary behavior as well as more sensitive to reductions in sitting time than the Actigraph GT3X™ (Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011). Differences in these two measures result from the fact that the Actigraph GT3X™ uses an accelerometer alone to classify sedentary, light, moderate, and vigorous intensity activity whereas the ActivPAL3™ monitor uses activity as well as postural data to classify behavior. Sedentary time was defined as time spent sitting or lying while awake. To calculate time spent sitting or lying down while awake, participants provided estimates of the time they went to sleep each night and woke each morning as part of the beginning of day questionnaire.

Planning. Action planning to limit sedentary behavior was assessed using three items (Sniehotta, Scholz, & Schwarzer, 2005). Participants reported the extent to which they had created a detailed plan regarding when, where, and how they plan to limit their sedentary behavior (e.g., “I have made a detailed plan on WHEN I will limit my sitting time today”). Coping planning to limit sedentary behavior was assessed using the single item adapted from previous research (Sniehotta et al., 2005). Participants reported the extent to which they had planned to limit their sitting time even if barriers arose (i.e., I have made a concrete plan on what to do so I can limit the time I spend sitting today even if I end up in situations that require me to sit a lot”). For both action and coping planning, participants provided ratings using a slider-type
interface, which was digitally coded on a 0 (not at all) to 100 (very much) scale. Action and coping planning items were highly correlated \((rs = .81-.91)\) so a composite item was created. To create this item, action planning items were averaged and then the average action planning item was averaged with the single coping planning item.

**Intentions.** Daily intentions to limit sedentary behavior were assessed using a 2-item measure adapted from previous research (Conroy, Maher, et al., 2013). Participants rated the extent to which they were willing to try to limit their sedentary behavior each day (e.g., “Today I intend to limit my sitting to less than 8 waking hours”). Participants provided ratings using a slider-type interface, which was digitally coded on a 0 (do not intend at all) to 100 (strongly intend) scale. Responses to these two items were strongly correlated at the between- and within-person level \((rs = .64 - .80)\), so we created an average intention score using the two items.

**Task self-efficacy.** Daily task self-efficacy to limit sedentary behavior was assessed using a 2-item measure adapted from previous research (Conroy, Maher, et al., 2013). Participants were asked to rate the extent to which they were confident that they could limit their sedentary behavior each day (e.g., “Today I believe I can limit my sitting to less than 8 waking hours”). Participants provided ratings using a slider-type interface, which was digitally coded on a 0 (not at all confident) to 100 (very confident) scale. Participants’ responses to these two items were strongly correlated at the between- and within-person level \((rs = .62 - .70)\), so we created an average task-self-efficacy score using these two items.

**Light-intensity physical activity outcome expectations.** Light-intensity physical activity outcome expectations were assessed using a modified version of the Multidimensional Outcome Expectations for Exercise Scale (Wójcicki, White, & McAuley, 2009), which consisted of 7 items. This scale was modified to reflect light-intensity physical activity outcome
expectations (e.g., “Regular light-intensity physical activity will improve my ability to perform daily activities”). Participants responded on a 0 (strongly disagree) to 4 (strongly agree) scale. For the purposes of this study, we removed the social domain items as well as 2 items each from the physical and self-evaluative domains from the original measure because there is not a documented link between light-intensity physical activity and those health outcomes (e.g., bone strength, muscular strength, stress management). Responses to the 7-item scale were internally consistent ($\sigma = 0.91$) and the score is reported as a mean of those response items.

**Sedentary behavior risk perceptions.** Sedentary behavior risk perceptions were assessed using a 8-item scale created for this study which included prominent health factors that have been associated with sedentary behavior in recent reviews (Biswas et al., 2015; de Rezende et al., 2014). Participants were asked to rate their perceptions of the risk associated with sitting for more than 8 waking hours each day (e.g., “Sitting for more than 8 waking hours each day will lead to premature death”). Participants responded on a 0 (strongly disagree) to 4 (strongly agree) scale. Responses to the 8-item scale were internally consistent ($\sigma = 0.89$) and the score is reported as a mean of those response items.

**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, & Bruijn, 2012; Verplanken & Melkevik, 2008; Verplanken & Orbell, 2003). The items in this subscale exclude items related to behavioral frequency. Participants reported how much they agreed with statements such as "Sitting is something [I do automatically/I do without thinking]" on 0 (strongly disagree) to 4 (strongly agree) scale. Responses to the 4-item scale were internally consistent ($\sigma = 0.89$) and the score is reported as a mean of those response items.
**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 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 (as described above). Time spent engaging in 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). We modified the checklist in two ways by (1) creating 4 symptom categories (musculoskeletal, gastrointestinal, cold and flu, and cardiovascular) out of the 23-item checklist and (2) asking participants to rate the severity of these symptoms rather than the presence or absence of the symptoms. This resulted in 4 items assessing physical symptoms. Participants rated the severity of these symptoms on a 0 (not at all) to 100 (very much) scale that used a slider-type interface. These responses were weakly-to-moderately correlated (rs = .23-.43) so we did not create an average physical symptoms score. Rather we included these four items separately in our models.

**Temporal processes.** First, to control for the possibility that motivation or behavior changed as a result of, or was reactive to, participating in the study we created a within-person
variable representing *exposure to the protocol*. The exposure variables accounted for the day in study. Second, we created six dummy variables representing the days of the week to account for possible effects of the *social calendar*. Saturday served as the reference day because sample-level average sedentary behavior was lowest on this day.

**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. Following standard multilevel modeling practice, 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). Pseudo-$R^2$ values should be interpreted with caution because of the fact that random variances in addition to the random variance associated with the intercept were included in the multilevel models. Data from the first and last days of the study were eliminated from analyses due to incomplete data on those days, resulting in a 13-day sample of motivation and behavior.

**Data preparation.** Daily ratings of predictor variables (e.g., task self-efficacy) were aggregated and person-centered to separate and simultaneously test between- and within-person associations (see Bolger & Laurenceau, 2013). For example, person $i$’s usual task self-efficacy (*Usual Task Self-Efficacy*$_i$) was calculated as the within-person mean of her daily self-reported task self-efficacy across days, and daily task self-efficacy (*Daily Task Self-Efficacy*$_{di}$) was calculated as the deviation of day $d$’s score from her usual task self-efficacy (i.e., cluster-mean centering; Enders & Tofghi, 2007). As such, the within-person mean scores across the 13 days
differentiate between people with higher or lower task self-efficacy, and, daily deviations
differentiate days on which people had higher or lower task self-efficacy than usual. Usual and
daily intentions, planning, physical activity, and physical symptoms were calculated in the same
way. Age and BMI as well as exposure to study variables were also group-mean and cluster-
mean centered, respectively.

**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:

**Level-1:** \[ \text{Sedentary Behavior}_{di} = \beta_0i + \beta_{1i}(\text{Daily Planning}_{di}) + \beta_{2i}(\text{Daily Physical Activity}_{di}) + \beta_{3i}(\text{Daily Musculoskeletal Symptoms}_{di}) + \beta_{4i}(\text{Daily Gastrointestinal Symptoms}_{di}) + \beta_{5i}(\text{Daily Cold/Flu Symptoms}_{di}) + \beta_{6i}(\text{Daily Cardiorespiratory Symptoms}_{di}) + \beta_{7i}(\text{Monday}_{di}) + \beta_{8i}(\text{Tuesday}_{di}) + \beta_{9i}(\text{Wednesday}_{di}) + \beta_{10i}(\text{Thursday}_{di}) + \beta_{11i}(\text{Friday}_{di}) + \beta_{12i}(\text{Sunday}_{di}) + \beta_{13i}(\text{StudyDay}_{di}) + e_{di} \] (1)

**Level-2:** \[ \beta_0i = \gamma_{00} + \gamma_{01}(\text{Usual Planning}_i) + \gamma_{02}(\text{Habit Strength}_i) + \gamma_{03}(\text{Usual Physical Activity}_i) + \gamma_{04}(\text{Usual Musculoskeletal Symptoms}_i) + \gamma_{05}(\text{Usual Gastrointestinal Symptoms}_i) + \gamma_{06}(\text{Usual Cold/Flu Symptoms}_i) + \gamma_{07}(\text{Usual Cardiorespiratory Symptoms}_i) + \gamma_{08}(\text{Sex}_i) + \gamma_{09}(\text{Age}) + \gamma_{10}(\text{BMI}_i) + u_{0i} \] (2)

\[ B_{1i} = \gamma_{10} + u_{1i} \] (3)

\[ \beta_{(2-13)i} = \gamma_{(2-13)0} \] (4)

where \( \gamma_{00} \) represents the average level of sedentary behavior for the average person in the sample,
\( \gamma_{01} \) to \( \gamma_{10} \) represent the between-person associations between usual planning to limit sedentary
behavior, habit strength, usual physical activity, usual musculoskeletal symptoms, usual
gastrointestinal symptoms, usual cold/flu symptoms, usual cardiorespiratory symptoms, sex, age,
and BMI with daily sedentary behavior (Sedentary Behavior_{di}), \( \gamma_{10} \) to \( \gamma_{130} \) represent the average
strength of the within-person influences of daily planning to limit sedentary behavior, daily physical activity, daily musculoskeletal symptoms, daily gastrointestinal symptoms, daily cold/flu symptoms, daily cardiorespiratory symptoms, day of the week, and the sequence of the day in the study, on daily sedentary behavior, and \( u_{0i} \) and \( u_{1i} \) are individual-level residual deviations that are uncorrelated with the day-level residuals \( e_{di} \). Separate models predicting daily sedentary behavior using self-reported and objectively-measured data were estimated.

Multilevel models predicting plans and intentions to limit sedentary behavior were also estimated. In the model predicting daily plans to limit sedentary behavior, daily task self-efficacy, daily intentions, daily musculoskeletal symptoms, daily gastrointestinal symptoms, daily cold/flu symptoms, daily cardiorespiratory symptoms, day of the week, and the sequence of the day in the study represented within-person effects on daily planning. The slopes associated with daily task self-efficacy and intentions were treated as random effects whereas all other within-person slopes were treated as fixed effects. Additionally, usual task self-efficacy, usual intentions, usual musculoskeletal symptoms, usual gastrointestinal symptoms, usual cold/flu symptoms, usual cardiorespiratory symptoms, sex, age, and BMI represented between-person effects on daily planning.

When predicting daily intentions to limit sedentary behavior, daily task self-efficacy, daily musculoskeletal symptoms, daily gastrointestinal symptoms, daily cold/flu symptoms, daily cardiorespiratory symptoms, day of the week, and the sequence of the day in study represented within-person effects on daily intentions. The slope associated with daily task self-efficacy was treated as a random effect. All other within-person slopes were treated as fixed effects. Usual task self-efficacy, outcome expectancies, risk perceptions, habit strength, usual musculoskeletal
symptoms, usual gastrointestinal symptoms, usual cold/flu symptoms, usual cardiorespiratory symptoms, sex, age, and BMI represented between-person effects on daily intentions.

**Results**

Participants provided self-reported motivation and behavioral data for a total of 1,238 of the 1,300 possible person-days (95% response rate). The median number of days participants provided self-report data was 13 days (M = 12.3, SD = 1.6). Participants provided valid objectively-measured data for a total of 1,196 of the 1,300 possible person-days (92% response rate). The median number of days participants provided objectively-measured data was 12 days (M = 11.9, SD = 1.5). 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. On average, participants reported engaging in more than 10 hours of sitting each day (M = 636.6 minutes). Objective data indicated that, on average, participants sat for slightly less than 10 hours each day (M = 573.7 minutes). On average, 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 average (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).

Between- and within-person correlations exhibited similar patterns. Self-reported and objectively-measured sedentary behavior were moderately correlated (rs = .38, .48). Sedentary behavior (self-reported and objectively-measured) had weak-to-moderate positive correlations with habit strength (rs = .22, .18) and weak-to-moderate negative correlations with planning (rs
Planning had moderate positive correlations with intentions \((rs = .51, .58)\). Intentions had strong positive correlations with task self-efficacy \((rs = .83, .83)\). Intentions also had weak-to-moderate positive correlations with sedentary behavior risk perceptions and light-intensity physical activity outcome expectations \((rs = .20, .06\), respectively\) at the between-person level. The intraclass correlation coefficients shown along the diagonal of the matrix in Table 2 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 between-person variance, with the remainder driven by within-person factors and measurement error.

**Predicting Sedentary Behavior**

Unstandardized parameter estimates from the multilevel models predicting behavior are presented in Table 2. The first model (left column of coefficients) regressed daily self-reported sedentary behavior on dual-process constructs, and the remaining covariates. The second model (right column of coefficients) regressed daily objectively-measured sedentary behavior on dual-process constructs and covariates. Sedentary behavior did not differ between people who tended to form stronger or weaker plans, but people were less sedentary on days when they formed stronger-than-usual plans to limit sedentary behavior \((self-reported behavior: \gamma_{10} = -0.79, p < .05; monitored behavior: \gamma_{10} = -0.51, p < .05)\). Consistent with hypotheses, sedentary behavior differed between people who tended to have stronger or weaker sedentary behavior habit strength \((self-reported behavior: \gamma_{02} = 36.32, p < .05; monitored behavior: \gamma_{02} = 19.97, p < .05)\). With respect to other covariates in the model of self-reported behavior, people were more sedentary on days when they experienced cold and flu symptoms that were more severe than usual \((\gamma_{40} = 1.18, p < .05)\). Regarding other covariates in the model of monitored behavior, men
engaged in more sedentary behavior compared to women ($\gamma_{08} = 57.13, p < .01$) and people engaged in more sedentary behavior on Wednesdays and Thursdays relative to Saturdays ($\gamma_{100} = 22.54; p < .05; \gamma_{110} = 30.48; p < .05$). No other covariates, in models of self-reported or monitored behavior, were significant predictors of sedentary behavior.

As indicated by the pseudo-$R^2$, the model predicting self-reported behavior accounted for approximately 13% of the variance in daily sedentary behavior, with daily planning accounting for 86% and habit strength accounting for 6% of the explained variance. Based on parameter estimates from the model using self-reported behavior, increasing the strength of daily plans to limit sedentary behavior by five units was associated with a decrease in sedentary behavior equivalent to the difference that occurs due to one year of aging. Likewise, increasing the strength of daily plans to limit sedentary behavior by 26 units was equivalent to the difference between weekend and weekday sedentary behavior. Increasing habit strength for sitting by one unit was equivalent to the difference in sedentary behavior over 10 years of aging. Likewise, increasing habit strength by slight more than half of one was equivalent to the difference between weekend and weekday sedentary behavior.

The model predicting objectively-measured behavior accounted for 14% of the variance, with daily planning accounting for 5% and habit strength accounting for 9% of the explained variance. Based on parameter estimates from the model using objectively-measured behavior, increasing the strength of plans to limit sedentary behavior by 66 units was associated with an increase in sedentary behavior equivalent to the difference that occurs due to one year of aging. Likewise increasing the strength of plans by 4.5 units was equivalent to the difference between weekend and weekday sedentary behavior. Increasing habit strength by one unit was equivalent to the difference in sedentary behavior over 4.5 years of aging. Increasing habit strength by slight
less than two units was equivalent to the difference between weekend and weekday sedentary behavior.

**Predicting Planning to Limit Sedentary Behavior**

Table 3 presents the unstandardized estimates from the multilevel model predicting plans to limit sedentary behavior. Plans to limit sedentary behavior differed between people who tended to have higher or lower task self-efficacy to limit sedentary behavior and people formed stronger plans on days when they had higher-than-usual task self-efficacy to limit sedentary behavior ($\gamma_{01} = -0.59, p < .05, \gamma_{10} = 0.14, p < .05$). Consistent with hypotheses, plans to limit sedentary behavior were stronger, on average, for people with stronger intentions to limit sedentary behavior and people formed stronger plans on days when they had higher-than-usual intentions to limit sedentary behavior ($\gamma_{02} = 1.17, p < .05, \gamma_{20} = 0.20, p < .05$). Regarding covariates, strength of plans tended to be weaker for older adults and as the study progressed ($\gamma_{08} = -0.70, p < .01, \gamma_{013} = -0.40, p < 0.01$). 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. Based on parameter estimates, increasing the strength of usual intentions to limit sedentary behavior by one unit was associated with an increase in plans to limit sedentary behavior equivalent to the difference that occurs due to two years of aging. Increasing the strength of usual intentions by less than two units was equivalent to the difference between weekend and weekday planning. Increasing the strength of daily intentions to limit sedentary behavior by more than three units was associated with an increase in plans to limit sedentary behavior.
sedentary behavior equivalent to the difference that occurs due to one year of aging. Increasing the strength of daily intentions by nine units was equivalent to the difference between weekend and weekday planning. Increasing the strength of usual task self-efficacy to limit sedentary behavior by more than one unit was associated with a decrease in plans to limit sedentary behavior equivalent to the difference that occurs due to one year of aging. Increasing the strength of usual task self-efficacy by three units was equivalent to the difference between weekend and weekday planning. Increasing the strength of daily task self-efficacy to limit sedentary behavior by five units was associated with an increase in plans to limit sedentary behavior equivalent to the difference that occurs due to one year of aging and increasing the strength of daily task self-efficacy by 13 units was equivalent to the difference between weekend and weekday planning.

**Predicting Intentions to Limit Sedentary Behavior**

Table 4 presents the unstandardized estimates from the multilevel model predicting intentions to limit sedentary behavior. Consistent with hypotheses, people who, on average, formed stronger intentions to limit sedentary behavior had higher task self-efficacy for limiting sedentary behavior and people formed stronger intentions when they had higher-than-usual task self-efficacy to limit sedentary behavior ($\gamma_{01} = 0.96$, $p < .05$, $\gamma_{10} = 0.61$, $p < .05$, respectively). Inconsistent with 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 ($\gamma_{02} = -0.11$, $\gamma_{03} = -0.67$, $\gamma_{04} = -0.16$, $ps > 0.10$). Regarding covariates, participants formed stronger intentions to limit sedentary behavior as the study progressed ($\gamma_{012} = 0.19$, $p < .05$). Intentions to limit sedentary behavior 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 89% and usual task self-efficacy accounting for 4% of the explained variance. Based on parameter estimates increasing the strength of usual task self-efficacy to limit sedentary behavior by one unit was associated with an increase in intentions to limit sedentary behavior equivalent to the difference that occurs due to six years of aging. Increasing the strength of usual plans by less than three units was equivalent to the difference between weekend and weekday intentions. Increasing the strength of daily task self-efficacy by one unit was associated with an increase in intentions to limit sedentary behavior equivalent to the difference that occurs due to four years of aging and increasing the strength of daily plans by less than four units was equivalent to the difference between weekend and weekday intentions.

**Discussion**

This study tested and provided support for the regulation of older adults’ sedentary behavior via dual-processes. Objectively-measured sedentary behavior revealed that the average participant sat for approximately 60% of their waking hours each day (= 9.5/15.75 hours). These findings are comparable to National Health and Nutrition Examination Survey 2003-2004 data in which accelerometer-derived sitting time suggested that adults age 60-69 sit for slightly less than 60% of their waking hours and adults age 70-85 sit for approximately 66% of their waking hours (Matthews et al., 2008). Interestingly self-reported sedentary time was greater, on average, than objectively-measured sedentary time by approximately one hour. Self-reported measures of sedentary behavior are generally thought to underestimate sitting time because of the highly habitual nature of sedentary behavior and therefore, a lack of awareness about the behavior; however, greater self-reported estimates of sitting time may reflect the domain-specific nature of
the measure used in this study (Conroy, Maher, et al., 2013; Kremers & Brug, 2008; Kremers, van der Horst, & Brug, 2007). Sedentary behavior can occur in a variety of domains and some domains of sedentary behavior may overlap (e.g., sitting while riding in a car and socializing with friends). 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 the cognitive demands associated with not double counting sitting time were too much for older adults. As older adults age, executive functioning declines and it may be that these declines make it difficult for older adults to accurately assign sedentary behavior that occurs in multiple domains to one domain without double counting the time (Salthouse, Atkinson, & Berish, 2003). The cognitively taxing nature of the self-reported domain-specific measure of sedentary behavior used in this study may account for greater levels of self-reported behavior compared to objectively-measured behavior.

This is the first study to extend previous findings about dual-processes regulating sedentary behavior to older adults. Individual differences in habit strength – reflecting a between-person, automatic process – consistently predicted sedentary behavior. Additionally, plans to limit sedentary behavior – a controlled process – was a consistent predictor of sedentary behavior at the within-person, but not between-person, level of analysis. These findings support arguments that dual-process theories of motivation are useful for explaining health behaviors across the lifespan (Conroy et al., 2011; Conroy, Maher, et al., 2013; Hofmann et al., 2008; Rebar, Elavsky, Maher, Doerksen, & Conroy, 2014). These results suggest that interventions designed to reduce sedentary behavior, in older adults and across the lifespan, should move beyond targeting only controlled motivational processes such as intentions, beliefs, and attitudes, and develop strategies that also target automatic motivational processes. Furthermore, findings
from this study suggest that motivational constructs that focus on avoiding an unwanted behavior (e.g., limiting sedentary behavior) are effective for predicting behavior; however, it is unclear if motivational constructs focusing on approaching a wanted behavior (e.g., increasing bouts of standing) would be more or less effective. Previous research has noted that avoidance-based goals generally involve less clearly defined strategies and are more likely to be associated with negative outcomes than approach-based goals (Elliot & Sheldon, 1997; Mann, de Ridder, & Fujita, 2013). Future research should investigate the extent to which intentions or plans to limit sedentary behavior are more or less effective than intentions or plans to stand or walk more.

Habits regulate much of our daily lives (Wood, Quinn, & Kashy, 2002), so it was not surprising that habit strength had some of the strongest bivariate correlations with older adults’ sedentary behavior. This association was robust in both multilevel models of sedentary behavior and leads to the conclusion that between-person differences in sedentary behavior are at least partly rooted in people’s habit strength for sedentary behavior. Additionally, this finding extends previous work in college students documenting a between-person association between habit strength and sedentary behavior (Conroy, Maher, et al., 2013). Developing detailed action plans or implementation intentions has been proposed as a way to break counter-intentional habits or create new habits (Gollwitzer & Sheeran, 2006; Orbell & Verplanken, 2010; Webb, Sheeran, & Luszczynska, 2009). Interventions that promote action planning can foster the development of new associations between cues in the environment and a desired behavior which can serve to disrupt counter intentional habits or create new, healthy habits in older adults. Older adults are likely to have stronger, more engrained habits because they have had more time to develop associations between cues in the environment and a behavioral response (Aarts et al., 1997; Verplanken et al., 2008). Therefore, the resources devoted to disrupting old habits and creating
new habits should be prioritized accordingly in interventions aiming to reduce older adults’ sedentary behavior.

Results from this study are the first to document planning as a bridge between intentions to limit sedentary behavior and older adults’ sedentary behavior. Developing detailed plans has long been recognized as a valuable tool for lessening the intention-behavior gap for health behaviors like physical activity (Bélanger-Gravel, Godin, & Amireault, 2011; Carraro & Gaudreau, 2013; Michie, Abraham, Whittington, McAteer, & Gupta, 2009; Rhodes & Pfaefli, 2010). However, this study documented that it is daily, but not usual, plans that are associated with behavior. Considering that planning and other controlled motivational constructs observed in this study varied significantly from day to day, it would suggest that interventions that are sensitive to this daily motivational variation may be more effective at reducing daily sedentary behavior. Therefore interventions aiming to reduce older adults’ sedentary behavior via planning should focus on having participants develop stronger action and coping plans on a given day and include daily booster sessions to facilitate that development. Future interventions employing planning as an intervention component should consider the framing of these plans. In a daily action planning intervention with a sample of college students, daily action plans to limit sedentary behavior were not associated with changes in daily sedentary behavior (Maher & Conroy, 2015). Effective action plans may result from focusing on promotion (e.g., plans to stand) rather than prevention (e.g., plans to limit sedentary behavior).

Results from this study also suggest that planning can be enhanced via daily task self-efficacy and usual and daily intentions to limit sedentary behavior. Interestingly, usual task-self efficacy was negatively associated with planning. This finding suggests that individuals who, on average, strongly believe they can limit their sedentary behavior are less likely to plan how to
limit their behavior because they are so confident in their ability to do so. Enhancing usual task self-efficacy as a way to facilitate planning is likely best suited for individuals with low usual task-self efficacy whereas enhancing daily or usual intentions or daily task self-efficacy is likely suitable for all individuals. Older adults may have particularly low levels of task self-efficacy and intentions to limit sedentary behavior due to pain or functional limitations, aging stereotypes, and previous failed attempts to engage in physical activity (Brawley et al., 2003; Sparling et al., 2015). However, results from this study suggest that even small changes in task self-efficacy or intentions are associated with stronger intentions or plans to limit sedentary behavior, respectively, which can promote behavior change.

Intention formation in this study appeared to be regulated by usual and daily task self-efficacy but not light-intensity physical activity outcome expectations, sedentary behavior risk perceptions, or habit strength. This is the first study to establish that task self-efficacy is associated with intentions to limit sedentary behavior through both between and within-person processes in older adults. This finding is consistent with qualitative data in older women, which suggests that older adults’ efficacy for limiting their sedentary behavior is a major determinant of time spent sitting (Chastin et al., 2014). However, quantitative work investigating the determinants of intentions to engage in sedentary activities found that instrumental and affective attitudes were the driving determinants of intention formation in community-based adults and college students (self-efficacy was not assessed in this study; Rhodes & Dean, 2009).

Instrumental attitudes reflect the extent to which a person believes engaging in sedentary behavior is a beneficial or harmful (similar to outcome expectancies and/or risk perceptions). These discrepant findings could be the results of the behavioral target of the intentions formed. Rhodes and Dean focused on predicting intentions to engage in sedentary activities whereas the
The current study focused on intentions to limit sedentary behavior (i.e., disengage in sedentary activities). Additionally, the use of counter-habitual intentions could also explain the null association between habits and intention formation, which was contrary to what Wood and Neal’s work on the habit-goal interface would predict (Wood & Neal, 2007). Results from this study suggest that interventions aiming to enhance intentions to limit sedentary behavior should focus on enhancing usual as well as daily task-self efficacy to limit sedentary behavior. For older adults, enhancing self-efficacy can result from strategies such as (1) providing mastery experiences where older adults engage in taking short breaks from sitting, (2) modeling where older adults learn from similar others the ways in which their peers are limiting or interrupting their sitting time, or (3) receiving encouragement from friends and family (Bandura, 1997).

Older adults’ sedentary behavior and motivational processes varied from day to day; 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. These trends have also been documented in college students (Conroy, Maher, et al., 2013). 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 such as playing games or attending club meetings.

Concerning exposure to study procedures, results from this study suggest there was not an association with behavior, but that planning and intentions did change as the study progressed. Previous research has documented that simply asking questions about undesirable health
behaviors can lead to increases in those behavior (Conroy, Maher, et al., 2013; Williams, Block, & Fitzsimons, 2006); however, these iatrogenic effects were not documented in this study. Therefore self-monitoring may be a useful component, at least to create awareness about the behavior, in interventions designed to reduce older adults’ sedentary behavior.

This study is not without limitations. The present sample was fairly homogeneous with respect to race and ethnicity. Non-Hispanic Black and Mexican American older adults both sit, on average, for more than 8 hours each day – a level of behavior that puts these ethnic minorities at elevated health risks (Matthews et al., 2008). Understanding the regulation of sedentary behavior in ethnic minorities is crucial to develop effective, possibly tailored, interventions to reduce sedentary behavior in older adults from various racial and ethnic backgrounds.

Although this study moved beyond traditional social cognitive theories of health behaviors by evaluating automatic processes that regulate behavior, it did not provide a complete test of the controlled processes that could influence behavior as outlined by HAPA. Examining the influence of perceived barriers and resources as well as maintenance and recovery self-efficacy will be crucial in understanding initiation and maintenance when reducing older adults’ sedentary behavior. This study also assessed habit strength using a self-reported measure. Although this is currently the only way to assess habit strength, it is somewhat controversial (Gardner et al., 2012; Sniehotta & Presseau, 2012). In our directions we provided participants with contexts during which sitting is a common behavior as a way to cue participants to the relevant cue-behavior linkages when responding. Additionally, this study focused on habits as an automatic process regulating behavior; however, other automatic processes such as, automatic evaluations of sitting as well as light-intensity physical activity, may also play a role in regulating behavior (Conroy, Hyde, Doerksen, & Ribeiro, 2010).
Lastly the automatic and controlled processes assessed in this study focused on prevention (i.e., sedentary behavior) rather than promotion (e.g., standing or walking). It is possible that conceptualizing sitting for an extended period of time as a behavior was challenging to participants. The term “sedentary” has most commonly been used to describe the absence of physical activity; however, recent calls have been made to use sedentary as a term that refers to activities that involve a seated or reclined position and expending little energy (Marshall & Ramirez, 2011; Pate, O’Neill, & Lobelo, 2008; Sedentary Behavior Research Network, 2012). We provided participants with a definition and examples of sedentary behavior that reflected this revised conceptualization of the term “sedentary” to help conceptualize the behavior that we were interested in assessing (i.e., sitting time). Future research would benefit from assessing not only sedentary behavior, but also the behaviors that displace sedentary behavior such as standing or walking as well as the motivational processes that regulate these alternative behaviors.

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. Both controlled and automatic processes contributed to the regulation of older adults’ sedentary behavior. These findings speak to the importance of understanding sedentary behavior through the lens of a dual-process theory of motivation. Understanding the dynamics between motivation and behavior can lead to the development of interventions that capitalize on those dynamics ultimately leading to more effective interventions to reduce sedentary behavior. Such efforts are especially relevant for our graying society given the accumulating evidence the excessive sedentary behavior is linked with a variety of negative health consequences in older adults.
References


Table 2.1
Descriptive statistics, correlations, and intraclass correlation coefficients of sedentary behavior, motivational constructs, and other variables of interest

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<th>M</th>
<th>SD</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>6.</th>
<th>7.</th>
<th>8.</th>
<th>9.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Daily objective sedentary behavior (min/day)</td>
<td>573.7</td>
<td>145.0</td>
<td>.55</td>
<td>.43</td>
<td>-.31</td>
<td>-.31</td>
<td>-.21</td>
<td>-.52</td>
<td>-.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Daily self-reported sedentary behavior (min/day)</td>
<td>636.6</td>
<td>219.9</td>
<td>.38</td>
<td>(.56)</td>
<td>-.20</td>
<td>-.24</td>
<td>-.10</td>
<td>-.38</td>
<td>-.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Daily intentions to limit sitting time</td>
<td>61.2</td>
<td>27.8</td>
<td>-.24</td>
<td>-.18</td>
<td>(.69)</td>
<td>.83</td>
<td>.58</td>
<td>.05</td>
<td>.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Daily efficacy to limit sitting time</td>
<td>61.9</td>
<td>27.1</td>
<td>-.19</td>
<td>-.22</td>
<td>.83</td>
<td>(.66)</td>
<td>.51</td>
<td>.08</td>
<td>.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Daily planning</td>
<td>43.9</td>
<td>31.4</td>
<td>-.19</td>
<td>-.11</td>
<td>.51</td>
<td>.45</td>
<td>(.70)</td>
<td>.02</td>
<td>.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Daily objective physical activity (min/day)</td>
<td>96.0</td>
<td>50.4</td>
<td>-.45</td>
<td>-.29</td>
<td>.07</td>
<td>.09</td>
<td>.05</td>
<td>(.42)</td>
<td>-.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Daily self-reported physical activity (MET•min•day⁻¹)</td>
<td>617.9</td>
<td>612.5</td>
<td>.09</td>
<td>.09</td>
<td>.21</td>
<td>.20</td>
<td>.17</td>
<td>.10</td>
<td>(.11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Sedentary behavior risk perception</td>
<td>2.8</td>
<td>0.9</td>
<td>.01</td>
<td>-.07</td>
<td>.20</td>
<td>.17</td>
<td>.17</td>
<td>.01</td>
<td>-.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Physical activity outcome expectations</td>
<td>3.2</td>
<td>0.8</td>
<td>.01</td>
<td>-.01</td>
<td>.06</td>
<td>.04</td>
<td>.14</td>
<td>.04</td>
<td>-.11</td>
<td>.34</td>
<td></td>
</tr>
<tr>
<td>10. Sedentary Behavior Habit Strength</td>
<td>2.2</td>
<td>1.1</td>
<td>.22</td>
<td>.18</td>
<td>-.21</td>
<td>-.20</td>
<td>-.18</td>
<td>-.24</td>
<td>.02</td>
<td>-.14</td>
<td>-.02</td>
</tr>
</tbody>
</table>

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).
Table 2.2
Multilevel coefficients predicting daily sedentary behavior (self-reported and objectively-measured)

<table>
<thead>
<tr>
<th>Model 1: Self-Reported Behavior</th>
<th>Model 2: Objectively-Measured Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed Effects</strong></td>
<td><strong>Parameter Estimate</strong></td>
</tr>
<tr>
<td><strong>Intercept</strong>, $\gamma_{00}$</td>
<td>52.84 (20.72)</td>
</tr>
<tr>
<td><strong>Usual Planning</strong>, $\gamma_{01}$</td>
<td>0.84 (2.01)</td>
</tr>
<tr>
<td><strong>Daily Planning</strong>, $\gamma_{10}$</td>
<td>-0.79* (0.33)</td>
</tr>
<tr>
<td><strong>Sedentary Behavior Habit Strength</strong>, $\gamma_{02}$</td>
<td>36.32* (16.65)</td>
</tr>
<tr>
<td><strong>Usual Physical Activity</strong>, $\gamma_{03}$</td>
<td>0.09* (0.04)</td>
</tr>
<tr>
<td><strong>Daily Physical Activity</strong>, $\gamma_{20}$</td>
<td>-0.04* (0.01)</td>
</tr>
<tr>
<td><strong>Usual Musculoskeletal Symptoms</strong>, $\gamma_{04}$</td>
<td>0.66 (0.88)</td>
</tr>
<tr>
<td><strong>Daily Musculoskeletal Symptoms</strong>, $\gamma_{30}$</td>
<td>0.06 (0.28)</td>
</tr>
<tr>
<td><strong>Usual Cold and Flu Symptoms</strong>, $\gamma_{05}$</td>
<td>0.84 (2.22)</td>
</tr>
<tr>
<td><strong>Daily Cold and Flu Symptoms</strong>, $\gamma_{40}$</td>
<td>1.18* (0.40)</td>
</tr>
<tr>
<td><strong>Usual Gastrointestinal Symptoms</strong>, $\gamma_{06}$</td>
<td>-1.07 (2.65)</td>
</tr>
<tr>
<td><strong>Daily Gastrointestinal Symptoms</strong>, $\gamma_{50}$</td>
<td>0.08 (0.39)</td>
</tr>
<tr>
<td><strong>Usual Cardiorespiratory Symptoms</strong>, $\gamma_{07}$</td>
<td>-3.68 (2.93)</td>
</tr>
<tr>
<td><strong>Daily Cardiorespiratory Symptoms</strong>, $\gamma_{60}$</td>
<td>-0.34 (0.47)</td>
</tr>
<tr>
<td><strong>Sex</strong>, $\gamma_{08}$</td>
<td>43.24 (38.78)</td>
</tr>
<tr>
<td><strong>Age</strong>, $\gamma_{09}$</td>
<td>3.82 (2.25)</td>
</tr>
<tr>
<td><strong>BMI</strong>, $\gamma_{010}$</td>
<td>6.79 (3.48)</td>
</tr>
<tr>
<td><strong>Sunday</strong>, $\gamma_{70}$</td>
<td>23.56 (14.88)</td>
</tr>
<tr>
<td><strong>Monday</strong>, $\gamma_{80}$</td>
<td>20.37 (15.43)</td>
</tr>
<tr>
<td><strong>Tuesday</strong>, $\gamma_{90}$</td>
<td>29.29 (15.28)</td>
</tr>
<tr>
<td><strong>Wednesday</strong>, $\gamma_{100}$</td>
<td>23.29 (15.36)</td>
</tr>
<tr>
<td><strong>Thursday</strong>, $\gamma_{110}$</td>
<td>1.77 (14.89)</td>
</tr>
<tr>
<td><strong>Friday</strong>, $\gamma_{120}$</td>
<td>8.56 (14.94)</td>
</tr>
<tr>
<td><strong>Day in Study</strong>, $\gamma_{130}$</td>
<td>1.55 (1.15)</td>
</tr>
<tr>
<td><strong>Random Effects</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Variance Intercept</strong>, $\sigma^2_{u0i}$</td>
<td>24434* (4017.84)</td>
</tr>
<tr>
<td><strong>Variance Planning</strong>, $\sigma^2_{u1i}$</td>
<td>3.92* (1.58)</td>
</tr>
<tr>
<td><strong>Residual</strong>, $\sigma^2_{uedi}$</td>
<td>18859* (853.41)</td>
</tr>
<tr>
<td><strong>-2LL</strong></td>
<td>14765.7</td>
</tr>
<tr>
<td><strong>AIC</strong></td>
<td>14733.7</td>
</tr>
</tbody>
</table>

**Note.** Unstandardized estimates and standard errors. Self-reported sedentary behavior model is based on 13 occasions nested within 100 participants for a total of 1194 observations. Objectively-measured sedentary behavior model is based on 13 occasions nested within 100 participants for a total of 1103 observations. \( AIC \) = Akaike Information Criterion. \(-2LL = -2 \log \text{Likelihood. *p < .05.}\)
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>(Standard Error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept, $\gamma_{00}$</td>
<td>117.15*</td>
<td>(26.28)</td>
</tr>
<tr>
<td>Usual Task Self-Efficacy, $\gamma_{01}$</td>
<td>-0.59*</td>
<td>(0.28)</td>
</tr>
<tr>
<td>Daily Task Self-Efficacy, $\gamma_{10}$</td>
<td>0.14*</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Usual Intentions, $\gamma_{02}$</td>
<td>1.17*</td>
<td>(0.27)</td>
</tr>
<tr>
<td>Daily Intentions, $\gamma_{20}$</td>
<td>0.20*</td>
<td>(0.05)</td>
</tr>
<tr>
<td>Usual Musculoskeletal Symptoms, $\gamma_{03}$</td>
<td>0.11</td>
<td>(0.11)</td>
</tr>
<tr>
<td>Daily Musculoskeletal Symptoms, $\gamma_{30}$</td>
<td>0.02</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Usual Cold and Flu Symptoms, $\gamma_{04}$</td>
<td>-0.21</td>
<td>(0.28)</td>
</tr>
<tr>
<td>Daily Cold and Flu Symptoms, $\gamma_{40}$</td>
<td>0.04</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Usual Gastrointestinal Symptoms, $\gamma_{05}$</td>
<td>0.18</td>
<td>(0.33)</td>
</tr>
<tr>
<td>Daily Gastrointestinal Symptoms, $\gamma_{50}$</td>
<td>0.01</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Usual Cardiorespiratory Symptoms, $\gamma_{06}$</td>
<td>0.38</td>
<td>(0.37)</td>
</tr>
<tr>
<td>Daily Cardiorespiratory Symptoms, $\gamma_{60}$</td>
<td>-0.01</td>
<td>(0.05)</td>
</tr>
<tr>
<td>Sex, $\gamma_{07}$</td>
<td>-2.05</td>
<td>(4.84)</td>
</tr>
<tr>
<td>Age, $\gamma_{08}$</td>
<td>-0.70*</td>
<td>(0.28)</td>
</tr>
<tr>
<td>BMI, $\gamma_{09}$</td>
<td>-0.69</td>
<td>(0.43)</td>
</tr>
<tr>
<td>Sunday, $\gamma_{70}$</td>
<td>1.14</td>
<td>(1.55)</td>
</tr>
<tr>
<td>Monday, $\gamma_{80}$</td>
<td>1.13</td>
<td>(1.62)</td>
</tr>
<tr>
<td>Tuesday, $\gamma_{90}$</td>
<td>-0.65</td>
<td>(1.60)</td>
</tr>
<tr>
<td>Wednesday, $\gamma_{100}$</td>
<td>0.08</td>
<td>(1.62)</td>
</tr>
<tr>
<td>Thursday, $\gamma_{110}$</td>
<td>0.75</td>
<td>(1.57)</td>
</tr>
<tr>
<td>Friday, $\gamma_{120}$</td>
<td>0.92</td>
<td>(1.57)</td>
</tr>
<tr>
<td>Day in Study, $\gamma_{130}$</td>
<td>-0.40*</td>
<td>(0.11)</td>
</tr>
</tbody>
</table>

**Random Effects**

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>(Standard Error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variance Intercept, $\sigma^2_{u0i}$</td>
<td>468.96*</td>
<td>(74.26)</td>
</tr>
<tr>
<td>Variance Task Self-Efficacy, $\sigma^2_{u1i}$</td>
<td>0.02</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Variance Intentions, $\sigma^2_{u1i}$</td>
<td>0.08*</td>
<td>(0.03)</td>
</tr>
<tr>
<td>Residual, $\sigma^2_{uedi}$</td>
<td>212.26*</td>
<td>(9.71)</td>
</tr>
<tr>
<td>$-2LL$</td>
<td>10210.7</td>
<td></td>
</tr>
<tr>
<td>$AIC$</td>
<td>10224.7</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Unstandardized estimates and standard errors. Model is based on 13 occasions nested within 100 participants for a total of 1198 observations. $AIC =$ Akaike Information Criterion. $-2LL = -2$ Log Likelihood. *$p < .05.$
Table 2.4
Multilevel coefficients predicting daily intentions to limit sedentary behavior

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Parameter Estimate</th>
<th>(Standard Error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept, $\gamma_{00}$</td>
<td>38.15*</td>
<td>(11.46)</td>
</tr>
<tr>
<td>Usual Task Self-Efficacy, $\gamma_{01}$</td>
<td>0.96*</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Daily Task Self-Efficacy, $\gamma_{10}$</td>
<td>0.61*</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Light-intensity Physical Activity Outcome Expectancies, $\gamma_{02}$</td>
<td>-0.11</td>
<td>(1.29)</td>
</tr>
<tr>
<td>Sedentary Behavior Risk Perceptions, $\gamma_{03}$</td>
<td>-0.67*</td>
<td>(1.12)</td>
</tr>
<tr>
<td>Sedentary Behavior Habit Strength, $\gamma_{04}$</td>
<td>-0.16</td>
<td>(0.84)</td>
</tr>
<tr>
<td>Usual Musculoskeletal Symptoms, $\gamma_{05}$</td>
<td>-0.01</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Daily Musculoskeletal Symptoms, $\gamma_{20}$</td>
<td>-0.02</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Usual Cold and Flu Symptoms, $\gamma_{06}$</td>
<td>0.08</td>
<td>(0.11)</td>
</tr>
<tr>
<td>Daily Cold and Flu Symptoms, $\gamma_{30}$</td>
<td>-0.02</td>
<td>(0.03)</td>
</tr>
<tr>
<td>Usual Gastrointestinal Symptoms, $\gamma_{07}$</td>
<td>-0.01</td>
<td>(0.13)</td>
</tr>
<tr>
<td>Daily Gastrointestinal Symptoms, $\gamma_{40}$</td>
<td>-0.01</td>
<td>(0.03)</td>
</tr>
<tr>
<td>Usual Cardiorespiratory Symptoms, $\gamma_{08}$</td>
<td>0.28</td>
<td>(0.15)</td>
</tr>
<tr>
<td>Daily Cardiorespiratory Symptoms, $\gamma_{50}$</td>
<td>-0.03</td>
<td>(0.03)</td>
</tr>
<tr>
<td>Sex, $\gamma_{09}$</td>
<td>-1.96</td>
<td>(1.99)</td>
</tr>
<tr>
<td>Age, $\gamma_{010}$</td>
<td>0.16</td>
<td>(0.11)</td>
</tr>
<tr>
<td>BMI, $\gamma_{011}$</td>
<td>0.30</td>
<td>(0.17)</td>
</tr>
<tr>
<td>Sunday, $\gamma_{60}$</td>
<td>-0.10</td>
<td>(1.24)</td>
</tr>
<tr>
<td>Monday, $\gamma_{70}$</td>
<td>-0.02</td>
<td>(1.30)</td>
</tr>
<tr>
<td>Tuesday, $\gamma_{80}$</td>
<td>-0.04</td>
<td>(1.27)</td>
</tr>
<tr>
<td>Wednesday, $\gamma_{90}$</td>
<td>0.15</td>
<td>(1.26)</td>
</tr>
<tr>
<td>Thursday, $\gamma_{100}$</td>
<td>-0.48</td>
<td>(1.25)</td>
</tr>
<tr>
<td>Friday, $\gamma_{110}$</td>
<td>-2.39</td>
<td>(1.25)</td>
</tr>
<tr>
<td>Day in Study, $\gamma_{120}$</td>
<td>0.19*</td>
<td>(0.09)</td>
</tr>
<tr>
<td>Random Effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance Intercept, $\sigma^2_{u0i}$</td>
<td>57.29*</td>
<td>(10.68)</td>
</tr>
<tr>
<td>Variance Task Self-Efficacy, $\sigma^2_{u1i}$</td>
<td>0.06*</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Residual, $\sigma^2_{uedi}$</td>
<td>129.38*</td>
<td>(6.03)</td>
</tr>
<tr>
<td>$-2LL$</td>
<td>9126.2</td>
<td></td>
</tr>
<tr>
<td>$AIC$</td>
<td>9140.2</td>
<td></td>
</tr>
</tbody>
</table>

Note. Unstandardized estimates and standard errors. Model is based on 13 occasions nested within 100 participants for a total of 1151 observations. $AIC$ = Akaike Information Criterion. $-2LL = -2 \text{Log Likelihood.} \ *p < .05.$
Figure Captions

Figure 2.1. 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.

Figure 2.2. Flow diagram created to clarify participation in 14-day daily diary study of older adults.

Figure 2.3. Revised dual process model based on study findings. Significant paths are in black ($p < 0.05$). Non-significant paths are in gray ($p > 0.05$).
Potential participants assessed for eligibility (n = 114)

- Excluded (n = 5)
  - Ineligible, n = 5
  - Sitting for < 8 hours/day, n = 5

Eligible (n = 109)

- Did not consent (n = 7)
  - Participant burden, n = 4
  - Family-related health issues, n = 3

Consented to participate (n = 102)

- Losses to follow-up (n = 1)
  - Participant burden, n = 1

Numbers participating at final wave of data collection (n = 101)

- Data excluded from analysis (n = 1)
  - Tablet malfunction, n = 1

Numbers including in data analysis (n = 100)
Chapter III: Daily Life Satisfaction in Older Adults as a Function of (In)Activity
Abstract

Older adults engage in excessive amounts of sedentary behavior and increased time spent sitting can adversely impact their well-being, independent of their physical activity. This 14-day daily diary study tested the between-person and within-person associations between sedentary behavior, physical activity, and life satisfaction in community dwelling older adults. Older adults (n = 100) wore ActivPAL3™ activity monitors for 14 days and, at the end of each day, answered questions regarding their health behaviors and life satisfaction. Separate multilevel models were tested for self-reported and objectively-measured behavioral data. In the model using objectively-measured behavioral data (1) sedentary behavior was negatively associated with life satisfaction at the within-person, but not the between-person, level, and (2) physical activity was not associated with life satisfaction at the between-person or within-person level. In the model using self-reported behavioral data (1) sedentary behavior was not associated with life satisfaction at the between-person or within-person level, and (2) physical activity was positively associated with life satisfaction at the within-person, but not the between-person, level. Results indicated that daily deviations in objectively-measured sedentary behavior and self-reported physical activity have implications for older adults’ well-being. Interventions designed to enhance well-being and quality of life in older adults should consider targeting daily changes in total sedentary behavior and daily changes in the volume or frequency of physical activity.
Daily Life Satisfaction in Older Adults as a Function of (In)Activity

Excessive sedentary behavior, or time spent sitting, is associated with poor psychological health in older adults; however, there is very little work investigating the association between sedentary behavior and life satisfaction in this population. Life satisfaction may be particularly relevant for older adults because it reflects the extent to which older adults are able to preserve quality of life in the face of advancing age and associated decreases in functional abilities (Rejeski & Mihalko, 2001). Additionally, life satisfaction is strongly associated with mortality in old age suggesting that life satisfaction is not only a desired subjective feeling but reflects a person’s health (Koivumaa-Honkanen et al., 2000; St John, Mackenzie, & Menec, 2015). Thus, life satisfaction is an important outcome in and of itself and can serve as an indicator of successful aging in older adults (Cho, Martin, & Poon, 2015; Fisher, 1992). This study aims to determine the association between objectively-measured and self-reported sedentary behavior, physical activity, and life satisfaction.

Life Satisfaction

Life satisfaction is commonly conceptualized as a cognitive evaluation of one’s life (Diener, 1984) and can represent how well a person’s current self aligns with her or his ideal self. Strategies for preserving and promoting life satisfaction among older adults are important given the graying of America and society's emphasis on not just adding years, but adding quality years to life (U.S. Census Bureau, 2008; West, Cole, Goodkind, & He, 2014). Health behaviors, such as sedentary behavior and physical activity, may play a role in that process. Understanding the association between these behaviors and life satisfaction may reveal new approaches to promoting successful aging in older adults.
Influences on life satisfaction can be framed as either between- or within-person (Maher et al., 2013). Top-down influences reflect stable individual differences that exert an influence on usual levels of life satisfaction (i.e. between-person process) whereas bottom-up influences reflect dynamic behaviors or states that exert an influence on daily life satisfaction (i.e., within-person process; Diener, 1984). Although between- and within-person factors both represent viable influences on life satisfaction, the majority of research concerning factors that influence life satisfaction has emphasized between-person influences whereas within-person influences have received limited attention.

**Life Satisfaction and Health Behaviors**

Health behaviors, like sedentary behavior and physical activity, may exert a between- or within-person influence, or both, on life satisfaction. Sedentary behavior and physical activity are health behaviors with established associations with indicators of global well-being at the between-person level (Biswa et al., 2015; de Rezende, Rey-Lópe, Matsudo, & do Carmo Luiz, 2014; Physical Activity Guidelines Advisory Committee, 2008; Teychenne, Ball, & Salmon, 2010). These associations reveal that the adults with the greatest well-being are those who have the least sedentary time and the most physical activity. These associations are likely mediated by individual differences in health (St John, Tyas, & Montgomery, 2013; Wilhelmson, Fritzell, Eklund, & Dahlin-Ivanoff, 2013).

Associations between daily sedentary behavior, daily physical activity and indicators of well-being (i.e., with-person processes) in older adults are less established. It may be that daily sedentary behavior is associated with life satisfaction through affective processes and daily physical activity is associated with life satisfaction through revitalization processes (Gauvin, Jack, & Rebourssin, 2000; Puett, O’Connor, & Dishman, 2006; Schwerdtfeger, Eberhardt,
Chmitorz, & Schaller, 2010). However, there has yet to be a study that has simultaneously examined associations between sedentary behavior, physical activity, and life satisfaction, at both the between- and within-person levels, in older adults.

**Distinguishing between sedentary behavior and physical activity.** Sedentary behavior and physical inactivity are conceptually different with the former referring to waking activities that take place in a seated or reclined posture and expend little energy and the latter referring to a lack of moderate- or vigorous-intensity physical activity (Marshall & Ramirez, 2011; Owen, Healy, Matthews, & Dunstan, 2010; Pate, O’Neill, & Lobelo, 2008). This distinction between sedentary behavior and physical activity is critical for two reasons. First, physical activity can displace sedentary behavior and confound interpretations of associations between sedentary behavior and life satisfaction. Only by differentiating these behaviors is it possible to evaluate whether any observed link is due to excessive sedentary behavior, insufficient physical activity, or both. Second, many health consequences of excessive sedentary behavior and insufficient physical activity are independent and additive so it is possible that each behavior has a unique effect on life satisfaction. Determining whether between- and within-person associations between sedentary behavior and life satisfaction are independent of physical activity is necessary to establish sedentary behavior as a health behavior with unique implications for older adults' life satisfaction.

**Life satisfaction and sedentary behavior.** Very little evidence is presently available regarding associations between sedentary behavior and life satisfaction. The majority of studies investigating associations between sedentary behavior and well-being have focused on negative indicators of well-being in older adults (e.g., depression, cognitive impairment; Hamer, Poole, & Messerli-Bürgy, 2013; Hamer & Stamatakis, 2013; Vance, Wadley, Ball, Roenker, & Rizzo,
Cross-sectional and prospective studies, have documented a positive association between self-reported sedentary behavior and depressive symptoms (Lucas et al., 2011; Vance et al., 2005; Van Uffelen et al., 2013). Other studies have documented a positive association between TV viewing (a common measure of sedentary behavior) and depressive symptoms (Hamer et al., 2013; Hamer & Stamatakis, 2013). Poorer cognitive functioning has also been associated with greater time spent in total sedentary activities and TV viewing (Da Ronch et al., 2015; Hamer & Stamatakis, 2013; Kesse-Guyot et al., 2012; Vance et al., 2005).

Evidence regarding the association between sedentary behavior and life satisfaction is available in adults and university students (Depp, Schkade, Thompson, & Jeste, 2010; Frey, Benesch, & Stutzer, 2007; Maher, Doerksen, Elavsky, & Conroy, 2014). In adults, greater levels of self-reported sedentary behavior (operationalized as time spent watching TV) are negatively associated with life satisfaction (i.e., a between-person association; Depp et al., 2010; Frey et al., 2007). In university students, Maher and colleagues found that, daily deviations in both self-reported and objectively-measured sedentary behavior were negatively associated with life satisfaction so that people experienced lower life satisfaction on days when they were more sedentary than was typical for them (i.e., a within-person association; Maher et al., 2014). In contrast, life satisfaction did not differ between people who, on average, were more or less sedentary (i.e., a between-person association). Based on these findings, it is possible that previously reported between-person associations between sedentary behavior and life satisfaction may be an artifact of an unmeasured within-person process over time. There has yet to be a study examining the association between sedentary behavior and life satisfaction at the between- and within-person level, simultaneously, in older adults. Addressing this gap in the literature is
important because older adults spend such a large amount of time in sedentary activities and life satisfaction can serve as an indicator of their success in the aging process.

**Life satisfaction and physical activity.** Cross-sectional and prospective studies examining the between-person association between physical activity and life satisfaction in older adults find that more active people generally tend to experience greater life satisfaction compared to less active peers (Courneya & Friedenreich, 1997, 1998; Elavsky et al., 2005; Elavsky & McAuley, 2005). However, these studies did not account for the within-person processes that may link physical activity and life satisfaction. Only one study to date has simultaneously investigated associations between physical activity and life satisfaction at both the between- and within-person level in older adults (Maher, Pincus, Ram, & Conroy, 2015). Older adults who engaged in greater usual levels of self-reported physical activity were more satisfied with their lives and on days when older adults were more physically active that was typical for them, they experienced greater life satisfaction. However, because results from this study did not account for sedentary behavior, it is not yet clear whether associations between physical activity and life satisfaction are due to overall physical activity volume itself or the displacement of sedentary behavior (Powell, Paluch, & Blair, 2011).

Previous research in college students found that both sedentary behavior and physical activity had additive within-person associations, but no between-person associations, with life satisfaction (Maher et al., 2014); however, it is unclear is these additive associations exist in older adults. There has yet to be a simultaneous examination of associations between sedentary behavior, physical activity, and life satisfaction in older adults.

Understanding the ways in which sedentary behavior and physical activity are associated with life satisfaction in older adults (i.e., via between- or within-person processes, or both), has
important implications for health behavior interventions designed to enhance quality of life in aging populations. This is the first study to simultaneously examine associations between sedentary behavior, physical activity, and life satisfaction in older adults, at the between- and within-person level.

The Present Study

To investigate the between and within-person associations between sedentary behavior, physical activity, and life satisfaction, a 14-day ecological momentary assessment study was conducted. This study employed both daily diary and ambulatory monitoring techniques. Both daily and usual sedentary behavior were hypothesized to be negatively associated with life satisfaction across both self-reported and objectively-measured behavior. Daily and usual physical activity were hypothesized to be positively associated with life satisfaction across both measures of behavior. In testing these hypotheses we statistically controlled for potential within-person confounds including daily physical symptoms, day-of-week, time-of-year, and time-in-study and potential between-person confounds such as overall physical symptoms, sex, age, body mass index (BMI).

Methods

To investigate associations between sedentary behavior and life satisfaction, this study used the same sample and procedures described in Chapter II of this dissertation.

Participants

Advertisements to recruit community-dwelling older adults were placed in local senior centers within central Pennsylvania, an online listing of community research studies, as well as distributed through the local Osher Life Long Learning Institute listserv. Participant flow is documented in Figure 1. Older adults (n = 114) expressed an interest in participating in the study.
Prospective participants were screened to determine eligibility. Inclusion criteria included (a) being 60 years or older and (b) self-reported sitting for an average of ≥ 8 hours/day. Exclusion criteria included (a) having been diagnosed by a physician as having dementia or Alzheimer’s Disease or (b) reporting any deficit in functional mobility as assessed by the walking and transferring subscales of the Instrumental Activities of Daily Living Scale (Lawton & Brody, 1969). The final sample comprised 67 women and 33 men. The sample was almost exclusively White (99%) and non-Hispanic (99%). The mean age of the sample was 74.2 years (SD = 8.2; Range: 60-89 years). Based on World Health Organization cutoffs for body mass index \( M = 27.3 \text{ kg/m}^2, \ SD = 5.3 \), participants were relatively evenly split between normal weight (38.6%), overweight (36.7%), and obese (23.7%).

**Procedures**

At that initial lab session, participants provided consent and completed a questionnaire regarding demographic information. Next, they were trained on study procedures and how to use a tablet computer to answer a brief questionnaire at the end of each day over the course of the 14-day study. Additionally, participants were also trained on how to affix and wear an ActivPAL3™ activity monitor on the front of their thigh (3-4 inches above the knee). Activity monitors were waterproofed to allow for continuous wear during sleeping and waking hours. Participants were instructed to remove the activity monitor only if they were engaging in any activities where the monitor would be submerged under water (i.e., bathing or swimming). For each of the next 14 days, participants answered a questionnaire at the end of each day on their tablet and wore their activity monitor. Participants returned to the lab twice over the course of the study: (1) on Day 7 to exchange their activity monitor and (2) on Day 14 to return the study equipment. All study procedures were approved by the local institutional review board.
Measures

**Demographics.** Demographic information included age, sex, race, ethnicity, and self-reported height and weight.

**Life satisfaction.** Daily life satisfaction was assessed using a single item from the Satisfaction with Life Scale (Diener, Emmons, Larsen, & Griffin, 1985) modified for daily administration (i.e., “I was satisfied with my life today”). Participants provided ratings using a slider-type interface, location along which is digitally coded on a 0 (*strongly disagree*) to 100 (*strongly agree*) scale. In an 8-day daily diary study, Maher et al. (2013) administered the complete 5-item Satisfaction with Life Scale and found that this item was most strongly associated with the latent life satisfaction factor. Additionally, using this single-item would reduce participant burden inherent in completing measures with multiple items assessing the same construct over extended periods of time.

**Objective sedentary behavior and physical activity.** ActivPAL3™ activity monitors (Physical Activity Technologies, Glasgow, Scotland) were used to measure sedentary behavior and physical activity objectively and have been validated in older adults (Grant, Dall, Mitchell, & Granat, 2008). The ActivPAL3™ monitor uses an inclinometer and accelerometer to measure posture and activity, respectively, and then classifies 15 second-long epochs as sitting/lying down, standing or stepping. Previous research comparing objective measures of sedentary behavior (i.e., ActivPAL3™, Actigraph GT3X™) to direct observation found that the ActivPAL3™ monitor was more precise in measuring sedentary behavior as well as more sensitive to reductions in sitting time than the Actigraph GT3X™ (Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011). Differences in these two measures result from the fact that the Actigraph GT3X™ uses an accelerometer alone to classify activity based on activity
counts in to sedentary, light, moderate, and vigorous intensity activity whereas the ActivPAL3™ monitor uses activity as well as postural data to classify behavior. Sedentary time was defined as time spent sitting or lying while awake. Therefore to calculate time spent sitting while awake, participants provided the time they went to sleep and the time they woke up each day. Time spent engaging in physical activity was defined as time spent stepping.

**Self-reported sedentary behavior and physical activity.** Daily self-reported sedentary behavior was assessed using a 9-item scale which features domain-specific sedentary activities which are commonly included in other validated measures of sedentary in adults and older adults (Gardiner et al., 2011; Visser & Koster, 2013). A domain-specific measure was employed to cue older adults to the variety of contexts in which sedentary behavior typically occurs to provide a more accurate estimate of total sedentary behavior. Items were modified to reflect daily sedentary time rather than weekly to reduce the threat of retrospective bias and recall errors (Matthews, Moore, George, Sampson, & Bowles, 2012). Participants were asked to report the time they spent sitting in each activity that day (i.e., watching TV, using the computer, reading, socializing with friends, in transit, completing hobbies, doing paperwork, eating, or any other activities) without double counting any times (e.g., counting time spent sitting using the computer and socializing as time using the computer or socializing but not both). Responses to these nine items were summed to create daily total sedentary behavior scores. Daily self-report physical activity was assessed using a modified version of the International Physical Activity Questionnaire (IPAQ), a validated measure of adult and older adult physical activity (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 et al.,
2013; Matthews et al., 2012). Standard scoring procedures for the IPAQ were used to convert duration of reported activities into metabolic equivalents (METs). Activity times were weighted by standard MET estimates (vigorous = 8, moderate = 4, walking = 3.3) and summed to create a daily PA MET•min•day\(^{-1}\) score (Sjöström et al., 2002, 2005).

**Physical Symptoms.** Physical symptoms were assessed using a modified version of the physical symptoms checklist (Larsen & Kasimatis, 1991). We modified the checklist in two ways by (1) creating four symptom categories (musculoskeletal, gastrointestinal, cold and flu, and cardiovascular) out of the 23-item checklist, and (2) asking participants to rate the severity of these symptoms rather than the presence or absence of the symptoms. These modifications resulted in 4 items assessing physical symptoms. Participants rated the severity of these symptoms on a 0 (not at all) to 100 (very much) scale that used a slider-type interface. These responses were weakly-to-moderately correlated (rs = .23-.43) so we did not create an average physical symptoms score. Rather we included these four items separately in our models.

**Temporal processes.** First, to control for the possibility that motivation or behavior changed as a result of, or was reactive to, participating in the study we created a within-person variable representing exposure to the protocol. The exposure variables accounted for the day in study (Godin, Bélanger-Gravel, Amireault, Vohl, & Pérusse, 2011). Second, we created six dummy variables representing the days of the week to account for possible effects of the social calendar. Saturday served as the reference day because life satisfaction for this sample was highest on that day.

**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. Following standard multilevel modeling practice, 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). Pseudo-\( R^2 \) values should be interpreted with caution because of the fact that random variances in addition to the random variance associated with the intercept were included in the multilevel models outlined below. Complete self-reported data was available on all study days, resulting in a 14-day sample of behavior and well-being. Complete objectively-measured data was not available on the first and last days of the study, resulting in a 13-day sample of behavior and well-being.

**Data preparation.** Daily ratings of predictor variables (e.g., sedentary behavior) were aggregated and person-centered to separate and simultaneously test between- and within-person associations (see Bolger & Laurenceau, 2013). For example, person \( i \)'s usual sedentary behavior \((Usual\ Sedentary\ Behavior_i)\) was calculated as the within-person mean of her daily sedentary behavior across days, and daily sedentary behavior \((Daily\ Sedentary\ Behavior_{di})\) was calculated as the deviation of day \( d \)'s score from her usual sedentary behavior (i.e., cluster-mean centering; Enders & Tofighi, 2007). As such, the within-person mean scores across the 14 days differentiate between more or less sedentary people, and, daily deviations differentiate more or less sedentary days. Usual and daily physical activity and physical symptoms were also calculated this way. Age and BMI as well as exposure to study variables were also group-mean and cluster-mean centered, respectively.

**Multilevel models.** In the multilevel models used to test hypotheses, life satisfaction on day \( d \) for person \( i \), \( Life\ Satisfaction_{di} \), was modeled as:
Level-1: $\text{Life Satisfaction} = \beta_{0i} + \beta_{1i}(\text{Daily Sedentary Behavior}_d) + \beta_{2i}(\text{Daily Physical Activity}_d) + \beta_{3i}(\text{Daily Musculoskeletal Symptoms}_d) + \beta_{4i}(\text{Daily Gastrointestinal Symptoms}_d) + \beta_{5i}(\text{Daily Cold/Flu Symptoms}_d) + \beta_{6i}(\text{Daily Cardiorespiratory Symptoms}_d) + \beta_{7i}(\text{Monday}_d) + \beta_{8i}(\text{Tuesday}_d) + \beta_{9i}(\text{Wednesday}_d) + \beta_{10i}(\text{Thursday}_d) + \beta_{11i}(\text{Friday}_d) + \beta_{12i}(\text{Sunday}_d) + \beta_{13i}(\text{StudyDay}_d) + e_i$  

Level-2: $\beta_{0i} = \gamma_{00} + \gamma_{01}(\text{Usual Sedentary Behavior}_i) + \gamma_{02}(\text{Usual Physical Activity}_i) + \gamma_{03}(\text{Usual Musculoskeletal Symptoms}_i) + \gamma_{04}(\text{Usual Gastrointestinal Symptoms}_i) + \gamma_{05}(\text{Usual Cold/Flu Symptoms}_i) + \gamma_{06}(\text{Usual Cardiorespiratory Symptoms}_i) + \gamma_{07}(\text{Sex}_i) + \gamma_{08}(\text{Age}) + \gamma_{09}(\text{BMI}_i) + u_{0i}$

$B_{1i} = \gamma_{10} + u_{1i}$

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

where $\gamma_{00}$ represents the average level of life satisfaction for the average person in the sample, $\gamma_{01}$ to $\gamma_{09}$ represent the between-person associations between usual sedentary behavior, usual physical activity, usual musculoskeletal symptoms, usual gastrointestinal symptoms, usual cold/flu symptoms, usual cardiorespiratory symptoms, sex, age, and BMI with daily life satisfaction (Life Satisfaction), $\gamma_{10}$ to $\gamma_{130}$ represent the average strength of the within-person influences of daily sedentary behavior, daily physical activity, daily musculoskeletal symptoms, daily gastrointestinal symptoms, daily cold/flu symptoms, daily cardiorespiratory symptoms, day of the week, and the sequence of the day in the study, on daily life satisfaction, and $u_{0i}$ and $u_{1i}$ are individual-level residual deviations that are uncorrelated with the day-level residuals $e_{di}$.

Separate models using daily self-reported and objectively-measured behavior to predict life satisfaction were estimated.
Results

Participants provided self-reported behavioral and life satisfaction data for a total of 1,313 of the 1,400 possible person-days (94% response rate). The median number of days participants provided self-report data was 14 days (M = 13.5, SD = 1.2). Participants provided valid objectively-measured data for a total of 1,196 of the 1,300 possible person-days (92% response rate). The median number of days participants provided objectively-measured data was 12 days (M = 11.9, SD = 1.5). Missing data (< 1%) was assumed to be missing completely at random.

Table 1 presents descriptive statistics and between- and within-person correlations between life satisfaction, sedentary behavior and physical activity (self-reported and objectively-measured), and control variables. On average participants reported moderate-to-high levels of daily life satisfaction (M = 78.5 on a 0 to 100 scale). Objectively-measured data indicated that, on average, participants engaged in sedentary behavior for approximately 9.5 waking hours each day whereas self-reported data indicated approximately 10.5 waking hours of sedentary behavior each day. Participant’s average level of objectively-measured daily physical activity was equivalent to approximately 1.5 hours of time spent moving whereas self-reported daily physical activity indicated that participants engaged in the equivalent of approximately 3 hours of walking each day. Physical symptoms reported by participants were rarely severe. On average, daily musculoskeletal symptoms were rated as more severe (M = 23.6 on a 0 to 100 scale) than the other daily physical symptoms (M ≤ 6.1), all t (1350) > 22.7, p < .05.

Between- and within-person correlations exhibited similar patterns. Life satisfaction had weak, negative correlations with self-reported and objectively-measured sedentary behavior (self-reported rs = -.01, -.05; objectively-measured rs = -.06, -.03). Life satisfaction had weak,
positive correlations with self-reported and objectively-measured physical activity (self-reported \( rs = .09, .15 \); objectively-measured \( rs = .01, .02 \)). Life satisfaction had weak-to-moderate correlations with physical symptoms (\( rs = -.14, -.41 \)). Measures of sedentary behavior were moderately and positively correlated (\( rs = .38, .43 \)). The intraclass correlation coefficients shown along the diagonal of the matrix in Table 1 indicated that approximately half of the variance in life satisfaction as well as self-reported and objectively-measured sedentary behavior was between-person variance, with the remainder driven by within-person factors and measurement error. For all other variables assessed at the daily level, 11% to 66% of the variance was between-person variance with the remaining variance accounted for by within-person variance and measurement error.

Unstandardized parameter estimates from the multilevel models predicting life satisfaction are presented in Table 2. The first model (left column of coefficients) regressed daily life satisfaction on objectively-measured behavior and the remaining covariates whereas the second model (right column of coefficients) regressed daily life satisfaction on self-reported behavior and the remaining covariates. Consistent with hypotheses, the model of objectively-measured behavior indicated that life satisfaction was lower on days when people were more sedentary than was typical for them (\( \gamma_{10} = -0.01, p < .05 \)); however, there was no difference in life satisfaction between more or less sedentary people. The association between life satisfaction and daily sedentary behavior varied across people (\( \sigma^2_{\text{u1i}} = 0.01, p < .05 \)). Additionally, life satisfaction did not differ between people who were more or less physically active on average or on days when people were more or less physically active than was typical for them.

Contrary to the hypothesis, the model of self-reported behavior indicated that life satisfaction did not differ between people who reported being more or less sedentary in general
or on days when people reported being more or less sedentary than was typical for them; however, the association between life satisfaction and daily sedentary behavior varied across people ($\sigma^2_{u1i} = 0.01, p < .05$). Life satisfaction was higher on days when people reported engaging in more physical activity than was typical for them ($\gamma_{20} = 0.002, p < .05$); however, life satisfaction did not differ between people who reported being more or less sedentary.

Across both objectively-measured and self-reported models, life satisfaction was higher for people (1) with a higher BMI (monitored behavior: $\gamma_{02} = 0.79, p < .05$; self-reported behavior: $\gamma_{02} = 0.61, p < .05$), (2) who experienced fewer musculoskeletal symptoms (monitored behavior: $\gamma_{03} = -0.24, p < .05$; self-reported behavior: $\gamma_{03} = -0.23, p < .05$) and (3) who experienced fewer cold and flu symptoms (monitored behavior: $\gamma_{04} = -0.54, p < .05$; self-reported behavior: $\gamma_{04} = -0.47, p < .05$) on average. Life satisfaction also was higher on days when people experienced fewer musculoskeletal symptoms than was typical for them (monitored behavior: $\gamma_{30} = -0.10, p < .05$; self-reported behavior: $\gamma_{30} = -0.08, p < .05$).

As indicated by the pseudo-$R^2$, The model using objectively-measured behavior to predict life satisfaction accounted for 8% of the variance in daily life satisfaction, with daily sedentary behavior for 72% of the explained variance. Based on parameter estimates from the model using objectively-measured behavior, one hour of daily sedentary behavior was associated with a decrease in life satisfaction equivalent to the difference that occurs due to five years of aging. Three hours of daily sedentary behavior was equivalent to the difference between weekend and weekday life satisfaction. The model using self-reported behavior to predict life satisfaction accounted for approximately 4% of the variance in daily life satisfaction, with daily physical activity for 17% of the explained variance. Based on parameter estimates from the model using self-reported behavior, twenty minutes of daily walking was associated with an
increase in life satisfaction equivalent to the difference that occurs due to one year of aging and over two hours of daily walking was equivalent to the difference between weekend and weekday life satisfaction.

These multilevel models were constructed on the assumption that the day’s health behaviors would influence end-of-day life satisfaction (as obtained by our assessment protocol). However, it is also possible that a given day’s sedentary behavior or physical activity may have been influenced by the previous evening’s life satisfaction. This alternative temporal sequence (i.e., previous day’s life satisfaction influencing current day’s health behaviors) was tested in a follow-up analysis where (1) daily objectively-measured sedentary behavior was regressed on daily previous-day life satisfaction and (2) daily self-reported physical activity was regressed on previous-day life satisfaction. When testing this model, (1) associations between sedentary behavior and life satisfaction were not significant at either the between- or within-person levels ($\gamma_{01} = -0.66, p = 0.34; \gamma_{10} = 0.07, p = .69$) and (2) associations between physical activity and life satisfaction were not significant at either the between- or within-person levels ($\gamma_{01} = 5.39, p = 0.08; \gamma_{10} = 0.66, p = .36$). Thus, we concluded that the between- and within-person associations between health behaviors and life satisfaction reflect the influence of behavior on self-evaluation rather than the influence of self-evaluation on behavior.

Discussion

This study was the first to simultaneously examine between- and within-person associations between older adults’ sedentary behavior, physical activity, and life satisfaction. It was also the first to examine those associations across objective and self-report measures of behavior. Usual levels of sedentary behavior and physical activity were consistently unrelated to older adults’ daily life satisfaction across both objective and self-report measures of behavior.
Results at the daily (within-person) level of analysis varied depending on whether the model used objective or self-report measures of sedentary behavior and physical activity. When using objectively-measured behavioral data, daily sedentary behavior was negatively associated with life satisfaction but daily physical activity was not linked with life satisfaction. When using self-reported behavioral data, daily sedentary behavior was unrelated to life satisfaction, but daily physical activity was positively associated with life satisfaction.

Previous research has consistently documented between-person associations between sedentary behavior and indicators of well-being in older adults; however, between-person associations between sedentary behavior and life satisfaction were not documented in this study. The null, between-person associations between sedentary behavior and life satisfaction, across both self-report and objective measures of behavior, may reflect the relatively good health status of our sample. Because of our exclusion criteria, all participants in this study did not have any physical limitations that prevented them from walking across a room or rising out of a chair on their own. Additionally, the average severity of physical symptoms (i.e., musculoskeletal, cold/flu, gastrointestinal, and cardiorespiratory) reported by participants was relatively low. Samples that include older adults with more diverse health status may exhibit a between-person association between sedentary behavior and life satisfaction (Balboa-Castillo, León-Muñoz, Graciani, Rodríguez-Artalejo, & Guallar-Castillón, 2011; Hamer & Stamatakis, 2013). Health-related processes are likely responsible for associations between usual sedentary behavior and life satisfaction in older adults. Excessive sedentary behavior is associated with a variety of negative health consequences in older adults (Biswa et al., 2015; de Rezende et al., 2014). These health consequences can interfere with older adults’ ability to complete activities of daily
living and maintain independence thus detracting from life satisfaction (Dogra & Stathokostas, 2012; Gennuso, Gangnon, Matthews, Thraen-Borowski, & Colbert, 2013).

Findings from models using objective and self-report behavioral data in this study conflict with previous findings regarding the between-person association between self-reported physical activity and life satisfaction in older adults (Maher et al., 2015). Maher et al. (2015) found that for midlife and older adults, but not emerging adults, usual levels of physical activity were positively associated with life satisfaction even after controlling for daily physical activity. That study only tested a linear age moderation term so it is possible that midlife, and not older adults, drove that between-person association. Results from this study revealed a null association between usual physical activity and life satisfaction across both self-reported and objective behavior. A likely mechanism linking usual physical activity and life satisfaction involves the health-related benefits associated with engaging in regular physical activity. Both studies were based on relatively healthy samples of older adults so differences in the association between physical activity and life satisfaction are not likely to be due to health status.

The physical activity measure used in the present study differed from the measure used by Maher et al. (2015). That study operationalized physical activity as the number of 10+ minute bouts of physical activity engaged in each day, regardless of duration (frequency), whereas this study operationalized self-reported physical activity as the average amount of energy expended based on minutes of physical activity per day (volume). Additionally the objective measure used in this study operationalized physical activity as time spent stepping (duration) because older adults’ engage in mostly light-intensity and relatively little moderate-vigorous intensity physical activity (Buman et al., 2010; Troiano et al., 2008). More frequent physical activity may make a greater contribution than the total volume or duration of physical activity to older adults’ daily
life satisfaction. More frequent bouts of physical activity likely reflect a more active lifestyle whereas higher volume or duration of physical activity may similarly reflect an active lifestyle or could also reflect a person who engages in recommended levels of physical activity at one particular time during the day but does little activity during the rest of the day. For older adults having a more active lifestyle and regularly dispersing activity throughout the day may have a greater impact on life satisfaction compared to obtaining recommended levels of physical activity in one bout.

Differences in the within-person association between sedentary behavior and life satisfaction may reflect ways in which self-report and objective measures capture sedentary behavior. As an objective measure of sedentary behavior, the ActivPAL3™ activity monitor measures posture and movement. These data are then used to determine whether a person is sitting or lying down, standing or stepping. Self-reported measures of behavior rely on a person to accurately recall time spent in various activities and then truthfully report that information. Accurately recalling sedentary behavior may be quite challenging for individuals at any age. Sitting is a pervasive behavior across the lifespan, with recent objective estimates suggesting that Americans, on average, spend nearly 8 waking hours each day sitting and older adults sitting upwards of 9 hours each day sitting (Harvey, Chastin, & Skelton, 2014; Matthews et al., 2008). Sedentary behavior is thought to be highly habitual so people may not be aware of how much time they sit each day (Conroy, Maher, Elavsky, Hyde, & Doerksen, 2013). Additionally, older adults face many challenges associated with aging, including declines in executive functioning (Salthouse, Atkinson, & Berish, 2003) that make it difficult for them to accurately recall their sedentary behavior. Executive functioning is an umbrella term used to describe a variety of cognitive processes including short term memory, problem solving, and reasoning. Although this
A sample was screened so as not to include older adults that had been diagnosed with dementia or Alzheimer’s disease, it is possible that participants in our sample were experiencing declines in executive functioning which made it difficult to accurately recall domain-specific estimates of sedentary behavior without double-counting that time.

Objective and self-reported measures of behavior were moderately correlated at both the within- and between-person level in this study. These correlations, although modest, are consistent with previous research regarding the extent of agreement between self-reported and objective measures of sedentary behavior (Barabone Gibbs et al., 2015; Biddle et al., 2012; Conroy et al., 2013; Maher et al., 2014).

Models of life satisfaction using self-report and objective behavioral data differed in their findings regarding associations between sedentary behavior and life satisfaction. Objective data that uses dual inclinometers and accelerometers to determine sitting time provides a more accurate estimate of sedentary behavior compared to self-report measures (Aguilar-Farías, Brown, Olds, & Peeters, 2014; Kozey-Keadle et al., 2011). Therefore, the model using objective behavioral data likely represents the true association between sedentary behavior and life satisfaction. Self-report data serves as a representation of older adults’ perceived time use. In this study perceived time use in different domains of sedentary behavior is likely influenced by a variety of factors including older adults’ values, interests, and goals as well as the level of enjoyment and stimulation during sedentary activities (Salmon, Owen, Crawford, Bauman, & Sallis, 2003). The null associations between older adults’ self-reported sedentary behavior and life satisfaction found in this study likely reflect those influences on perceived time use rather than actual sitting time.
Results from the model using self-report behavioral data suggest that the nature of the activity may be important in understanding relations between sedentary behavior and life satisfaction. The extent to which older adults find certain sedentary activities meaningful or rewarding represents an important area of research because it can identify sedentary activities that can enhance or detract from life satisfaction. Previous work has indicated that adults often find sedentary activities to be as, if not more, enjoyable than moderate- or vigorous-intensity physical activity (Salmon et al., 2003). This work would ultimately inform behavior change targets in interventions designed to reduce sedentary behavior.

The majority of studies that have used self-reported sedentary behavior to establish associations between sedentary behavior and indicators of well-being have used single-item measures to assess total time spent sitting or have focused on a single domain of sedentary behavior (e.g., TV viewing) to classify older adults as more or less sedentary (Balboa-Castillo et al., 2011; Da Ronch et al., 2015; Hamer et al., 2013; Hamer & Stamatakis, 2013; Vance et al., 2005). Single-item measures of sedentary behavior may be less susceptible to the factors that influence perceived time use because participants are asked to reflect on their total sedentary behavior rather than report times for individual domains. Future research employing domain-specific measures of sedentary behavior would benefit from investigating the properties of activities that seem to be linked with more or less life satisfaction.

This study added to accumulating evidence that objectively-measured sedentary behavior is associated with life satisfaction and this association reflects a within-person process (Maher et al., 2014). Unlike previous studies which only examined associations between sedentary behavior and indicators of well-being at the between-person level (Balboa-Castillo et al., 2011; Hamer et al., 2013; Hamer & Stamatakis, 2013; Lucas et al., 2011; Vance et al., 2005), this study
examined those associations simultaneously and revealed a significant within-person, but not between-person, association. It may be that previously documented associations between sedentary behavior and indicators of well-being at the between-person level were an artifact of unaccounted for within-person processes. The within-person association between sedentary behavior and life satisfaction may be driven by affective processes. Previous research in adults indicated that acute bouts of sedentary behavior were associated with reduced positive affect and enhanced negative affect (Schwerdtfeger et al., 2010). Compared to a seated position, standing and walking require greater cognitive and attentional resources that can lead to less rumination and negative affect among older adults (Maylor & Wing, 1996; Teasdale & Simoneau, 2001). Work regarding embodied cognition, or the school of thought that the body can play an important role in cognitive and affective processes, also supports claims that sedentary behavior may influence life satisfaction through affect. For example, previous research has documented that slouched postures can enhance feelings of helplessness and that upright postures can enhance feelings of self-worth (Briñol, Petty, & Wagner, 2009; Chisholm, Risko, & Kingstone, 2013; Riskind & Gotay, 1982). Therefore when older adults sit, they are likely to experience less positive affect and more negative affect, which can interfere with their ability to effectively pursue their goals and color a person’s cognitive evaluation of their life on a given day, detracting from life satisfaction.

Other possible within-person mechanisms may include thwarted goal pursuits or low perceived control. Individuals who spend excessive amounts of time sitting due to obligations such as doctors’ appointments, social or volunteering obligations, and meetings may feel that the time they spend sitting actually interferes with other goal pursuits. Spending excessive amounts
of time engaging in sedentary behavior due to obligations may also decrease feelings of perceived control.

Previous research in college students documented a within-person association between objectively-measured physical activity and life satisfaction (Maher et al., 2014). Differences between this study and previous research may reflect differences in the objective measures of physical activity. In the study by Maher et al. (2014), physical activity was expressed as average hourly volume (activity counts/hour) whereas, in this study, physical activity was expressed as duration (time spent stepping/day). Volume is the product of intensity and duration. Thus the major difference in these conceptualizations of objectively-measured physical activity is that in this study physical activity was void of any information about intensity of the physical activity. It may be that older adults need to engage in a certain intensity of physical activity to enhance well-being. Federal physical activity guidelines recommend that older adults engage in regular moderate- or vigorous-intensity physical activity to accrue health benefits (Physical Activity Guidelines Advisory Committee, 2008). It may be that reaching these specified intensities, through popular modes of activity like brisk walking, is necessary for older adults to enhance their well-being. Future research investigating within-person associations between objectively-measured physical activity and life satisfaction in older adults should incorporate measures of activity that capture the volume of physical activity.

This study adds to accumulating evidence that daily deviations in self-reported physical activity are associated with life satisfaction across the lifespan (Maher et al., 2015). Previous studies examining this within-person association have included a variety of self-reported measures of physical activity including modified versions of the IPAQ (physical activity operationalized as the average amount of energy expended based on minutes of physical activity
per day; Sjöström et al., 2002, 2005) as well as the Godin Leisure Time Exercise Questionnaire (physical activity operationalized as the number of 10-minute bouts of physical activity per day; Godin, Jobin, & Bouillon, 1986). A likely mechanism that accounts for this association involves the revitalizing effect of physical activity. When people feel exhausted, they are less likely to pursue relevant goals. Physical activity has a revitalizing effect, which is likely to increase resource availability for goal pursuits (Gauvin et al., 2000; Kanning & Schlicht, 2010; Thayer, 1996). Increased resources for goal pursuits should facilitate striving for and achieving relevant goals and, therefore, are likely to result in increased life satisfaction.

Looking across both behavioral models, the findings from this study suggest that sedentary behavior and physical activity do not have additive associations with life satisfaction in older adults. This finding is contrary to studies that documented independent and additive associations with physiological health and well-being (Balboa-Castillo et al., 2011; Hamer et al., 2013; Hamer & Stamatakis, 2013; Kesse-Guyot et al., 2012; Van Uffelen et al., 2013). However, the lack of independent associations may be due to differences in measurement previously outlined. Using objective measures of behavior that are not subject to the influences that can affect people’s perceived time use (e.g., values, interests, goals) may yield the strongest conclusions regarding these additive associations. Furthermore, results from this study suggest that objective measures of physical activity that capture volume or frequency, as opposed to duration, may be most appropriate for documenting associations between physical activity and life satisfaction in older adults.

Results from this study suggest that older adults need not make dramatic, sustained changes in their behavior to increase their life satisfaction. Small changes in daily life (e.g., taking the stairs instead of the elevator [to increase daily physical activity] or standing during the
commercial breaks [to reduce sedentary behavior]) may have a greater impact on life satisfaction than more dramatic, sustained changes in behavior (i.e., adopting a new exercise program or removing all chairs from one’s home). Furthermore these small changes are likely to be more manageable and easier to incorporate into daily life. Interventions designed to enhance well-being and quality of life in older adults should consider targeting daily changes in total sedentary behavior and daily changes in the volume or frequency of bouts of physical activity.

Some limitations of this study should be noted. First, our sample was heterogeneous with respect to race and ethnicity. Both life satisfaction and health behaviors, such as sedentary behavior and physical activity, can differ by race (Clemente & Sauer, 1976; Matthews et al., 2008; Troiano et al., 2008). Additionally, for the purpose of this study, we excluded participants that were unable to rise out of a chair or walk on their own. Therefore our sample was relatively healthy. Future research is needed in populations of pre-frail and frail older adults because their sedentary behavior is problematic and may accelerate declines in health (Blodgett, Theou, Kirkland, Andreou, & Rockwood, 2015). Investigating these associations in more diverse samples will be critical in understanding how health behaviors can be used as a way to promote well-being and quality of life in aging populations.

Additionally, life satisfaction and sedentary behavior were assessed at the end of each day. The fact that participants completed assessments at the end of each day may have impacted results due to fatigue or circadian processes (e.g., melatonin, cortisol, blood pressure). Moreover, problems inherent with recall, as previously outlined, may have obscured participants’ self-reports of behavior. Therefore, it may be valuable to sample life satisfaction, as well as sedentary behavior, at different times throughout the day to further untangle the association between sedentary behavior and life satisfaction, while reducing recall burden. Such a study could use
current technology (i.e., smartphones) to assess sedentary behavior and life satisfaction on other time scales (e.g., event-contingent recording).

Furthermore, the observational nature of this study precludes conclusions about causality. We tested and were able to rule out one plausible alternative causal sequence to strengthen confidence in our conclusions. Additionally, we also controlled for several plausible time-varying and time-invariant third variables. With that said a number of other plausible third variables were not controlled (e.g., perceived control, goal pursuits, positive and negative affect). Experimental work is needed to determine the casual role that sedentary behavior and physical activity play in regulating life satisfaction.

In conclusion, this study elaborated on associations between sedentary behavior, physical activity, and life satisfaction in older adults. Associations differed between self-report and objective measures of behavior. Objective measures are more accurate measures of behavior because they rely solely on accelerometer and inclinometer data to categorize activity and can provide a clearer picture of associations between sedentary behavior, physical activity, and life satisfaction. Self-reported measures of health behaviors are likely to be influenced by the extent to which older adults’ time use aligns with their values, interests, goals, and level of stimulation during activities and may distort associations between these health behaviors and life satisfaction. Results from this study suggest that daily changes in sedentary behavior or physical activity, but not both, have implications for older adults’ well-being. Usual sedentary behavior and physical activity were not associated with older adults’ well-being. Interventions designed to enhance well-being and quality of life in older adults should emphasize daily changes in total sedentary behavior and daily changes in the volume or frequency of physical activity.
References


Courneya, K. S., & Friedenreich, C. M. (1997). Relationship between exercise pattern across the
cancer experience and current quality of life in colorectal cancer survivors. *The Journal of
Alternative and Complementary Medicine, 3*(3), 215–226.

and current quality of life among survivors of breast cancer. *Journal of Psychosocial
Oncology, 15*(3-4), 35–57. http://doi.org/10.1300/J077v15n03_02

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., …
Oja, P. (2003). International physical activity questionnaire: 12-country reliability and

Da Ronch, C., Canuto, A., Volkert, J., Massarenti, S., Weber, K., Dehoust, M. C., … Grassi, L.
(2015). Association of television viewing with mental health and mild cognitive
impairment in the elderly in three European countries, data from the MentDis_ICF65+
project. *Mental Health and Physical Activity, 8*, 8–14.
http://doi.org/10.1016/j.mhpa.2014.11.002

experience, and television use. *American Journal of Preventive Medicine, 39*(2), 173–
178.

Sedentary behavior and health outcomes among older adults: A systematic review. *BMC


*Journal of Personality Assessment, 49*(1), 71–75.


http://doi.org/10.1016/j.bbi.2013.05.001


http://doi.org/10.1249/MSS.0000000000000156


http://doi.org/10.1016/S0966-6362(01)00134-5


Table 3.1
Descriptive statistics, correlations, and intraclass correlation coefficients of life satisfaction, sedentary behavior, physical activity, and other variables of interest

<table>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Life satisfaction</td>
<td>78.5</td>
<td>21.5</td>
<td>-.03</td>
<td>-.05</td>
<td>.02</td>
<td>.15</td>
<td>-.36</td>
<td>-.41</td>
<td>-.37</td>
<td>-.37</td>
<td>-.25</td>
</tr>
<tr>
<td>2. Daily objective sedentary behavior (min/day)</td>
<td>573.7</td>
<td>145.0</td>
<td>-.06</td>
<td>.43</td>
<td>-.52</td>
<td>-.01</td>
<td>.01</td>
<td>-.03</td>
<td>.01</td>
<td>.01</td>
<td>.04</td>
</tr>
<tr>
<td>3. Daily self-reported sedentary behavior (min/day)</td>
<td>636.6</td>
<td>219.9</td>
<td>.38</td>
<td>-.38</td>
<td>-.31</td>
<td>.14</td>
<td>.01</td>
<td>.01</td>
<td>.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Daily objective physical activity (min/day)</td>
<td>96.0</td>
<td>50.4</td>
<td>.01</td>
<td>-.45</td>
<td>-.29</td>
<td>(42)</td>
<td>-.09</td>
<td>-.19</td>
<td>.01</td>
<td>.01</td>
<td>-.11</td>
</tr>
<tr>
<td>5. Daily self-reported physical activity (MET•min•day⁻¹)</td>
<td>617.9</td>
<td>612.5</td>
<td>.09</td>
<td>.09</td>
<td>.10</td>
<td>(11)</td>
<td>.23</td>
<td>.10</td>
<td>.18</td>
<td>.18</td>
<td>.34</td>
</tr>
<tr>
<td>6. Daily musculoskeletal symptoms</td>
<td>23.6</td>
<td>27.8</td>
<td>-.24</td>
<td>.01</td>
<td>.09</td>
<td>-.11</td>
<td>.15</td>
<td>(66)</td>
<td>.31</td>
<td>.46</td>
<td>.49</td>
</tr>
<tr>
<td>7. Daily cold/flu symptoms</td>
<td>6.1</td>
<td>15.5</td>
<td>-.22</td>
<td>.01</td>
<td>.05</td>
<td>-.01</td>
<td>.06</td>
<td>.24</td>
<td>(.44)</td>
<td>.66</td>
<td>.57</td>
</tr>
<tr>
<td>8. Daily gastrointestinal symptoms</td>
<td>5.9</td>
<td>14.4</td>
<td>-.17</td>
<td>.02</td>
<td>.01</td>
<td>-.03</td>
<td>.09</td>
<td>.30</td>
<td>.43</td>
<td>(.36)</td>
<td>.55</td>
</tr>
<tr>
<td>9. Daily cardiorespiratory symptoms</td>
<td>4.7</td>
<td>12.2</td>
<td>-.14</td>
<td>.02</td>
<td>.01</td>
<td>-.04</td>
<td>.16</td>
<td>.33</td>
<td>.37</td>
<td>.36</td>
<td>(.38)</td>
</tr>
</tbody>
</table>

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).
Table 3.2  
Multilevel coefficients predicting daily life satisfaction

<table>
<thead>
<tr>
<th></th>
<th>Model 1: Objectively-Measured Behavior</th>
<th>Model 2: Self-Reported Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Parameter Estimate (Standard Error)</td>
<td>Parameter Estimate (Standard Error)</td>
</tr>
<tr>
<td>Fixed Effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept, $\gamma_{00}$</td>
<td>48.26* (17.20)</td>
<td>49.97* (16.71)</td>
</tr>
<tr>
<td>Usual Sedentary Behavior, $\gamma_{01}$</td>
<td>-0.01 (0.01)</td>
<td>-0.01 (0.01)</td>
</tr>
<tr>
<td>Daily Sedentary Behavior, $\gamma_{10}$</td>
<td>-0.01* (0.005)</td>
<td>-0.01 (0.01)</td>
</tr>
<tr>
<td>Usual Physical Activity, $\gamma_{02}$</td>
<td>0.02 (0.05)</td>
<td>0.01 (0.01)</td>
</tr>
<tr>
<td>Daily Physical Activity, $\gamma_{20}$</td>
<td>0.01 (0.05)</td>
<td>0.002* (0.001)</td>
</tr>
<tr>
<td>Usual Musculoskeletal Symptoms, $\gamma_{03}$</td>
<td>-0.24* (0.07)</td>
<td>-0.23* (0.07)</td>
</tr>
<tr>
<td>Daily Musculoskeletal Symptoms, $\gamma_{30}$</td>
<td>-0.10* (0.03)</td>
<td>-0.08* (0.03)</td>
</tr>
<tr>
<td>Usual Cold and Flu Symptoms, $\gamma_{04}$</td>
<td>-0.54* (0.17)</td>
<td>-0.47* (0.17)</td>
</tr>
<tr>
<td>Daily Cold and Flu Symptoms, $\gamma_{40}$</td>
<td>-0.03 (0.04)</td>
<td>-0.04 (0.04)</td>
</tr>
<tr>
<td>Usual Gastrointestinal Symptoms, $\gamma_{05}$</td>
<td>-0.15 (0.21)</td>
<td>-0.26 (0.21)</td>
</tr>
<tr>
<td>Daily Gastrointestinal Symptoms, $\gamma_{50}$</td>
<td>0.02 (0.04)</td>
<td>0.02 (0.04)</td>
</tr>
<tr>
<td>Usual Cardiorespiratory Symptoms, $\gamma_{06}$</td>
<td>0.22 (0.22)</td>
<td>0.11 (0.23)</td>
</tr>
<tr>
<td>Daily Cardiorespiratory Symptoms, $\gamma_{60}$</td>
<td>0.05 (0.05)</td>
<td>-0.05 (0.05)</td>
</tr>
<tr>
<td>Sex, $\gamma_{70}$</td>
<td>0.13 (3.13)</td>
<td>-0.09 (2.89)</td>
</tr>
<tr>
<td>Age, $\gamma_{80}$</td>
<td>0.12 (0.18)</td>
<td>0.16 (0.17)</td>
</tr>
<tr>
<td>BMI, $\gamma_{90}$</td>
<td>0.79* (0.30)</td>
<td>0.61* (0.28)</td>
</tr>
<tr>
<td>Sunday, $\gamma_{07}$</td>
<td>-0.19 (1.67)</td>
<td>-0.39 (1.67)</td>
</tr>
<tr>
<td>Monday, $\gamma_{08}$</td>
<td>-2.08 (1.74)</td>
<td>-2.23 (1.65)</td>
</tr>
<tr>
<td>Tuesday, $\gamma_{09}$</td>
<td>-1.73 (1.74)</td>
<td>-1.03 (1.67)</td>
</tr>
<tr>
<td>Wednesday, $\gamma_{10}$</td>
<td>-0.77 (1.74)</td>
<td>-1.14 (1.65)</td>
</tr>
<tr>
<td>Thursday, $\gamma_{11}$</td>
<td>-1.55 (1.70)</td>
<td>-1.86 (1.66)</td>
</tr>
<tr>
<td>Friday, $\gamma_{12}$</td>
<td>-0.34 (1.68)</td>
<td>0.44 (1.66)</td>
</tr>
<tr>
<td>Day in Study, $\gamma_{13}$</td>
<td>-0.01 (0.12)</td>
<td>-0.01 (0.11)</td>
</tr>
<tr>
<td>Random Effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance Intercept, $\sigma^2_{u0i}$</td>
<td>148.86* (25.70)</td>
<td>150.13* (25.45)</td>
</tr>
<tr>
<td>Variance Sedentary Behavior, $\sigma^2_{u1i}$</td>
<td>0.01* (0.001)</td>
<td>0.01* (0.001)</td>
</tr>
<tr>
<td>Residual, $\sigma^2_{uedi}$</td>
<td>243.68</td>
<td>356.20</td>
</tr>
<tr>
<td>-2LL</td>
<td>9732.9</td>
<td>11258.7</td>
</tr>
<tr>
<td>AIC</td>
<td>9738.9</td>
<td>11266.7</td>
</tr>
</tbody>
</table>

Note. Unstandardized estimates and standard errors. Model 1 (left column of coefficients) regressed daily life satisfaction on objectively-measured behavior, and the remaining covariates. Model 2 (right column of coefficients) regressed daily life satisfaction on self-reported behavior, and the remaining covariates. Multilevel models are based on 14 and 13 occasions nested within 100 participants for a total of 1,313 self-reported and 1,196 objectively-measured observations, respectively. AIC = Akaike Information Criterion. -2LL = -2 Log Likelihood. *p < .05.
Figure Captions

Figure 3.1. Flow diagram created to clarify participation in 14-day daily diary study of older adults.
Potential participants assessed for eligibility (n = 114)

- Excluded (n = 5)
  - Ineligible, n = 5
  - Sitting for < 8 hours/day, n = 5

Eligible (n = 109)

- Did not consent (n = 7)
  - Participant burden, n = 4
  - Family-related health issues, n = 3

Consented to participate (n = 102)

- Losses to follow-up (n = 1)
  - Participant burden, n = 1

Numbers participating at final wave of data collection (n = 101)

- Data excluded from analysis (n = 1)
  - Tablet malfunction, n = 1

Numbers including in data analysis (n = 100)
Chapter IV: Feasibility and Preliminary Efficacy of a Brief Intervention to Reduce Older Adults’ Sedentary Behavior
Abstract

A handful of interventions have been designed to reduce sedentary behavior in older adults; however, many of these interventions require trained personnel which limits the potential for broad dissemination. This study evaluated the feasibility, acceptability, safety, and preliminary efficacy of a brief intervention to reduce sedentary behavior in older adults that can be broadly disseminated and delivered by paraprofessionals with limited training and for limited cost. Rural senior centers in the northeastern United States (n = 5) were stratified by size and cluster randomized to receive one of two healthy aging intervention programs. Participants were community dwelling older adults (n = 42) electively participating in senior center programming. The intervention consisted of psychoeducational videos interspersed with group discussions related to the motivational strategies that older adults can use to reduce their sedentary behavior. Repeated-measures ANOVA revealed a significant group X time interaction for total and weekday, but not weekend, sedentary behavior. In the experimental group, weekday sedentary behavior decreased by approximately 132.6 minutes/day ($d = -0.83$) whereas weekday sedentary behavior in the control group decreased by 24 minutes/day ($d = -0.16$). Participants' attendance, measurement completion and ratings of the program were high. Safety issues were minimal. This intervention was feasible to implement and evaluate, acceptable to older adults, and showed great promise for reducing older adults’ weekday sedentary behavior.
Feasibility and Preliminary Efficacy of a Brief Intervention to Reduce Older Adults’ Sedentary Behavior

Adults age 65 and older represent one of the fastest-growing segments of the population and the most sedentary with older adults, on average, sitting to more than 9 waking hours each day (Harvey, Chastin, & Skelton, 2014; Matthews et al., 2008; U.S. Census Bureau, 2008; West, Cole, Goodkind, & He, 2014). Sedentary behavior is especially problematic for older adults because it detracts from the only form of physical activity engaged in by many older adults (i.e., light-intensity physical activity; Smith, Ekelund, & Hamer, 2015; Sparling, Howard, Dunstan, & Owen, 2015). Additionally, sedentary behavior is associated with poor health profiles, greater functional limitations, and impaired cognitive functioning in older adults (Gennuso, Gangnon, Matthews, Thraen-Borowski, & Colbert, 2013; Hamer & Stamatakis, 2013). As evidence accumulates regarding the dangerous consequences associated with excessive sedentary behavior and its implications for successful aging, the need for effective interventions to reduce sedentary behavior has become paramount. To date only a handful of interventions have been developed to reduce sedentary behavior in older adults; however, these interventions often used face-to-face counseling with a trained interventionist or technologies, such as smartphones, which currently have limited adoption among older adults (Chang, Fritschi, & Kim, 2013; Fitzsimons et al., 2013; Gardiner, Eakin, Healy, & Owen, 2011; King et al., 2013; Smith, 2014). These barriers limit the potential for widespread dissemination and implementation of existing approaches. In the interest of developing a scalable intervention, video (for delivering expert-informed content) was combined with group discussions to be led by paraprofessionals with limited specialized training (to increase user engagement). This study evaluated the feasibility, acceptability, safety,
and initial efficacy of that brief intervention in community senior centers to reduce older adults’ sedentary behavior.

**Interventions to Date in Older Adults**

Physical activity contributes to successful aging in older adults (Physical Activity Guidelines Advisory Committee, 2008). Interventions to promote moderate- to vigorous-intensity physical activity have had small-to-medium size effects on older adults’ behavior (Chase, 2013; Conn, Valentine, & Cooper, 2002). However, exercise may not be practical for all older adults. Exercise can be an impractical or unfeasible behavior for older adults because of functional limitations, aging stereotypes, and the fatigue, soreness, and pain associated with engaging in physical activity (Brawley, Rejeski, & King, 2003; Lunt et al., 2014; Schutzer & Graves, 2004). For those adults who cannot reasonably engage in exercise, light-intensity physical activity provides an opportunity to accrue health benefits (Blair et al., 2014; Buman et al., 2010, 2013; Thraen-Borowski, Trentham-Dietz, Edwards, Koltyn, & Colbert, 2013). One strategy for increasing light-intensity physical activity is to reduce sedentary behavior. Displacing sedentary behavior with light-intensity physical activity provides an opportunity for older adults to make healthy lifestyle changes without drastically altering their behavior (Smith et al., 2015; Sparling et al., 2015).

To date there have been a handful of studies evaluating interventions to reduce older adults’ sedentary behavior. These interventions have been linked with reductions in total or weekday sedentary time ranging from 9 to 76 min/day and 24 to 35 min/day based on self-report and objective measures, respectively (Chang et al., 2013; Fitzsimons et al., 2013; Gardiner, Eakin, et al., 2011). Although these effects are promising, the potential to scale these interventions to improve population health is limited by the need for interventionists with...
specialized training and the expense of providing either individual behavior coaching or extensive group counseling (Chang et al., 2013; Fitzsimons et al., 2013; Gardiner, Eakin, et al., 2011).

Technology based-interventions have the potential to reach a large number of individuals while limiting face-to-face contact with trained researchers and conserving resources. King et al. (2013) recently employed a smartphone-based intervention designed to reduce older adults’ sedentary behavior. Although modest reductions in sedentary behavior were noted in that intervention (similar to face-to-face interventions), it was limited in that it could only reach older adults who have smartphones. Although the prevalence of smartphones is growing, recent data from the Pew Research Center suggests that fewer than 20% of adults over age 60 own a smartphone (Smith, 2014). Low-cost, scalable interventions that employ familiar technology would be valuable for reducing older adults’ sedentary behavior and promoting successful aging.

Video provides an alternative mode for delivering expert content knowledge in a low-cost manner that is more likely to reach older adults in the community (Thraen-Borowski et al., 2013). Videos are useful for unidirectional information transfer but may fail to engage older adults sufficiently in behavior change. This limitation can be addressed by combining videos that deliver intervention content from an expert with paraprofessional-led group discussions based on scripted questions aimed at stimulating an open dialogue of reflections on and common experiences with intervention content. This discussion process can make intervention content more personally-meaningful and stimulate peer influence.

**Applying a Dual-Process Model to Intervene on Older Adults’ Sedentary Behavior**

Previous interventions to reduce sedentary behavior in older adults have all generalized the social-cognitive approaches used to promote physical activity to reduce sedentary behavior.
Research supports the notion that the determinants of sedentary behavior are dual-process in nature (Conroy, Maher, Elavsky, Hyde, & Doerksen, 2013).

Dual-process theories of motivation posit that both controlled and automatic processes regulate our behavior (Hofmann, Friese, & Wiers, 2008; Smith & DeCoster, 2000). Controlled processes are conscious, effortful, slow, and volitional and include constructs outlined in social-cognitive theories of motivation (e.g., intentions, efficacy beliefs, attitudes). Automatic processes are nonconscious, effortless, fast, and unintended and can include constructs like habits. Habits develop through the repeated pairing of a contextual cue within the environment and a behavioral response so that, over time, encountering the cue automatically elicits the behavioral response (Aarts, Paulussen, & Schaalma, 1997). We developed the present intervention based on a dual-process model which considers both the controlled and automatic motivational processes that regulate sedentary behavior.

To account for the automatic motivational processes that regulate behavior, we relied on previous work, as well as results from this dissertation, which suggests that habits to engage in sedentary behavior are a direct influence on behavior (Conroy et al., 2013). To account for the controlled motivational processes that regulate sedentary behavior, we used the Health Action Process Approach (HAPA) to inform our intervention (Schwarzer et al., 2007a). The dual-process framework used to inform this intervention is depicted in Figure 1.

The HAPA is a social-cognitive theoretical model which has successfully been applied to explain the controlled motivational processes that regulate a range of health behaviors including condom use, seatbelt use, physical activity, and dental hygiene (Schwarzer et al., 2007a). One of the main tenets of HAPA is that behavior change involves both a motivational phase and a volitional phase. Individuals develop intentions to change behavior in the motivational phase,
and then translate those intentions into behavior in the volitional phase. The habitual nature of much sedentary behavior, which has been established in this dissertation as well as previous work, suggests that simply forming intentions to reduce sedentary behavior will not be sufficient to change behavior (Conroy et al., 2013). Rather, efforts need to be made to overcome sedentary habits when attempting to translate intentions into behavior. Therefore, the inclusion of the volitional phase in the HAPA model makes it an ideal theoretical framework to serve as the basis for an intervention to reduce sedentary behavior in older adults.

Like other social-cognitive theories, the HAPA posits three common determinants of intention formation: task self-efficacy, outcome expectations, and risk perception. Task self-efficacy refers to the extent to which an individual believes they can successfully engage in a particular behavior (e.g., I believe I can stand for 5 minutes each waking hour today). Outcome expectations refer to the perceived effectiveness of a behavior in producing a desired outcome (e.g., engaging in regular light-intensity physical activity will lead to improved cardiovascular functioning). Risk perceptions reflect the extent to which an individual believes a behavior will produce an undesired outcome (e.g., sitting for 8+ hours per day will lead to weight gain).

The HAPA model recognizes that the act of developing intentions is often not sufficient to change behavior – a phenomenon known as the intention-behavior gap (Sheeran, 2002). Rather the HAPA model proposes that volitional processes are crucial for translating intentions into behavior. Specifically, intentions are translated into behavior through the process of developing detailed plans for implementing the intention (Gollwitzer & Sheeran, 2006). Action planning involves specifying the details of when, where, and how to act in the service of one’s intentions (e.g., on Sunday afternoon while watching TV, I will stand during the commercial breaks). Coping planning involves identifying how one will overcome the potential barriers or
obstacles that could get in the way of the goal striving process (e.g., If I am driving for a long period of time, I will stop every hour and stand for 5 minutes).

The HAPA model also specifies other volitional processes that contribute to the translation of intentions into behavior. Maintenance and recovery self-efficacy are proposed to be key components of the volitional process as are perceived barriers and resources at the intrapersonal, interpersonal, and environmental levels. Developing maintenance and recovery self-efficacy as well as coping plans and identifying barriers and resources are not targeted in this brief intervention because some experience with the new behavior is needed before these beliefs can develop so they are better suited for attention in a follow-up session.

The components of this brief intervention targeted task self-efficacy, outcome expectations, and risk perceptions to facilitate intention formation, and action planning and habits to facilitate the translation of those intentions into behavior.

**The Present Study**

This study was designed to evaluate the feasibility, acceptability, safety, and preliminary efficacy of a brief intervention to reduce sedentary behavior among older adults at community senior centers. Following intervention development, a 14-day intervention was delivered at five senior centers in rural Pennsylvania. We hypothesized that it would be feasible to implement and evaluate this brief intervention for reducing sedentary behavior with older adults and that the intervention would be acceptable, safe, and efficacious for reducing total, weekday, and weekend sedentary behavior.

**Methods**

**Participants**
This study took place between February and April 2014 at five senior centers in rural Pennsylvania. Inclusion criteria for senior centers in this study included (a) being located within Centre County, Pennsylvania and (b) being open to the public. Centers were excluded if senior center managers did not express an interest in offering this successful aging program at their senior center. Inclusion criteria for older adults interested in participating in this study included (a) being age 60 or older and (b) participating in programs at a local community senior center. Exclusion criteria for the study included having (a) been diagnosed by a physician as having dementia or Alzheimer's disease, or (b) injuries or illnesses that precluded standing or walking. Participants who met the eligibility criteria were asked to participate in the study which consisted of three, one-and-a-half hour meetings over the next two weeks.

Cluster randomization was used to reduce the threat of design contamination. Randomization was stratified based on center size using data from the county’s Office of Aging. Senior centers were considered small \( (n = 3) \) or large \( (n = 2) \) if they had less or more than 30 regular attendees, respectively. The computer-generated allocation sequence yielded one large and two small senior centers in the experimental group and one large and one small senior center in the control group.

**Intervention**

Content for the experimental and control groups focused on reducing sedentary behavior and social isolation, respectively. Social isolation was chosen for the control group because, similar to sedentary behavior, the number and quality of social interactions a person has can have implications for a person’s physical and mental health (Buchman et al., 2010; Cohen, 2001; Holwerda et al., 2012; Seeman et al., 2011) and isolation increases with age (Wrzus, Hänel, Wagner, & Neyer, 2013). Content in both groups involved watching video segments and
participating in group discussions with other older adults participating in the study. Video segments included content that targeted controlled and automatic motivational processes. Essential components of the intervention are outlined below and summarized in Table 1.

**Part I.** The function of part I of the intervention was to clearly define sedentary behavior as well as create awareness about the behavior. Prior to the beginning of the intervention, participants were asked to estimate the number of hours they spent sitting on an average day in the last week. Participants then watched a video segment that defined sedentary behavior and provided examples of sedentary behavior. The definition and examples were in accordance with the definition of sedentary behavior provided by the Sedentary Behavior Research Network (2012).

After defining sedentary behavior, participants were asked to complete a self-reported measure of their domain-specific sedentary behavior in the last week on a tablet computer. Participants responded to each domain-specific sedentary behavior item on a tablet computer which then generated a total number of hours spent sitting on an average day based on participants’ responses. The discussion leader then asked to compare this sum to their initial guess of the number of hours they spent sitting on an average day in the last week. The discussion leader asked participants if they were surprised by the tablet computer-generated total and possible reasons why there might have been a discrepancy between participants’ initial guesses and the tablet computer-generated total.

**Part II.** The function of part II of the intervention was again to create awareness regarding sedentary behavior, place individuals’ sedentary behavior in perspective relative to their peers’ sedentary behavior, and guide intention formation and plans to limit sedentary behavior. In part II, participants watched a video segment that described normative estimates of
sedentary behavior across the adult lifespan. Normative data was based off of objectively-measured sedentary time that described sedentary behavior in adults age 20 – 85 years (Matthews et al., 2008). Particular emphasis was paid to the amount of time adults age 60 and over spend sitting. The video reviewed that although the average adult sits for 7.7 hours per day, adults age 60 and over, on average, sit for approximately 9 waking hours per day. Additionally, the video segment highlighted that adults also tend to sit more on weekend days than on weekdays. The discussion leader then posed a series of questions to participants asking them if anyone sat for more than 9 hours per day or if anyone sat for less than 9 hours per day and how the time they spent sitting differed from weekdays to weekend days.

Part III. The function of part III of the intervention was to enhance outcome expectancies for light-intensity physical activity and risk perceptions for sedentary behavior. Additionally, a group activity that involved standing for a short period of time (approximately 5 minutes) was designed to enhance task self-efficacy for interrupting sitting time during this part of the intervention. In part III, participants watched a video segment that reviewed the available evidence to determine if sitting too much is a dangerous behavior. All evidence presented focused on the increased risk associated with sitting for more than 8 hours per day or the reduced risk associated with sitting for less than 8 hours per day. The video segment began by reviewing some of the first evidence regarding the dangers of sitting as outlined in the classic London Double Decker Bus Study (Morris, Heady, Raffle, Roberts, & Parks, 1953). Thereafter, the video segment outlined the risk associated with excessive sitting regarding premature death (Biswas et al., 2015; de Rezende, Rey-López, Matsudo, & do Carmo Luiz, 2014), cardiovascular disease (Gennuso et al., 2013), type-II diabetes (Bey & Hamilton, 2003), weight gain (Hamilton, Hamilton, & Zderic, 2007), aspects of mental health such as depressive symptoms and quality of
life (Hamer & Stamatakis, 2013). The video segment also reviewed the benefits of limiting sedentary behavior or displacing sedentary behavior with light-intensity physical activity. Specifically, these benefits reviewed in the video focused on decreased risk of premature death (van der Ploeg, Chey, Korda, Banks, & Bauman, 2012), cardiovascular disease (Buman et al., 2013), type-II diabetes (Dunstan et al., 2012), as well as opportunities for weight maintenance or even weight loss (Buckley, Mellor, Morris, & Joseph, 2013) and maintaining physical and cognitive function (Gennuso et al., 2013; Hamer & Stamatakis, 2013). When available, information regarding the mechanisms associated with these consequences or benefits was also described. Following this segment, participants were asked to stand while answering discussion questions, posed by the discussion leader. The discussion leaders asked participants to comment on the consequences and benefits presented, either because of their own personal experiences or family history. Upon completion of this discussion topic, the discussion leader reminded participants that taking short breaks from sitting throughout the day, similar to the bout of standing participants just engaged in, can add up over time and positively impact their physical and mental health.

**Part IV.** The function of part IV of the intervention was to clearly define action planning and provide participants with an opportunity to create their own action plans to enact over the next week. Developing action plans was intended to strengthen counterhabitual plans to limit sedentary behavior and disrupt sitting habits. In preparation for part IV, participants were asked to identify (1) times during the day or activities when they typically sat for at least 30 minutes at a time and (2) ways that participants might be able to break up that sitting time by standing or moving during those periods of extended sitting. Participants then shared and discussed their ideas with the group.
A video segment then defined action planning and how action plans were created. The video segment focused on developing action plans that specified when, where, and how participants would break up or limit their sitting time over the next week. Three examples were provided of how participants could use the information developed in the previous activity to specify the when, were, and how of an action plan. One such example noted that if participants found themselves sitting for long periods of time while watching televisions then a resultant plan might be, “On weekday mornings while at home watching the news, I will stand during the commercial breaks.” Then participants were asked to use their responses from the previous activity to develop three action plans that specified when, where, and how they would interrupt or limit their sitting time. Participants were also asked to share at least one plan with the group. Developing and sharing action plans served to provide a bridge between intentions and behavior as well as increase accountability for following through with those plans.

**Part V.** The function of part V of the intervention was to identify target behavioral goals over the next week to guide intention formation and enactment of action planning. In part V, a video segment identified target behavioral goals that participants should strive to achieve over the next week. The first behavioral goal asked participants to strive to stand or move for at least 10 minutes each waking hour over the next week. The second behavioral goal, served as a more challenging goal, and asked participants to attempt to limit their sitting time to less than 8 waking hours each day over the course of the next week.

**Outcome Measures**

**Feasibility.** Feasibility was measured as the participation, adherence, response, and measurement completion rates among participants. *Participation* was based on the number of senior centers that had meaningful recruitment (≥5 senior center patrons) out of the total number
invited. Adherence was calculated as percentage of participants who attended all three sessions and the percentage of sessions attended by participants. Measurement completion was calculated as the percentage of total observations obtained out of the total observations possible across all participants and occasions.

**Acceptability.** Acceptability was measured using four items created for this study. Participants were asked to rate various aspects of the program on a 5-point Likert scale including the program’s relevance to the participant’s daily life (ranging from 0 [not relevant at all] to 4 [very relevant]), and quality of video, quality of presenter, and overall quality of the program (ranging from 0 [not good at all] to 4 [very good]). With these items we attempt to capture this intervention’s potential for adoption. Responses were moderately-to-strongly correlated (.26-.76) and were averaged to create a single acceptability score (α = .81).

**Safety.** Safety was assessed using the classification of adverse events described by Ory et al. (2005). Participants reviewed a list of potential adverse events and marked any they experienced as a result of standing or walking in the past week. These events included falling, temporary shortness of breath, dizziness, elevated blood pressure, acute myocardial infarction, chest pains, arrhythmia, or stroke, muscle soreness, non-routine doctor’s visits, and hospitalization.

**Sedentary behavior.** Sedentary time was estimated by summing time spent in nine common domains of sedentary behavior. The measure created by Gardiner et al. (Gardiner, Clark, et al., 2011) served as the basis for this measure and was supplemented with additional activities from Visser and Koster (2013). The sedentary activities included time spent sitting or lying down while (1) watching TV, (2) using the computer, (3) reading, (4) socializing with friends, (5) in transit, (6) completing hobbies, (7) doing paperwork, (8) eating, or (9) any other
activities. Participants were asked to report their average time spent engaging in each sedentary activity on a typical weekday and a typical weekend day over the past week (18 items total). Responses to each version of the measure were summed to create separate scores for sedentary behavior on weekdays and weekend days. A weekly sedentary behavior score was calculated by weighting these respective scores (\( = [5 \times \text{weekday sedentary behavior}] + [2 \times \text{weekend day sedentary behavior}] \)).

**Procedures**

This study lasted 2 weeks and there were three sessions over the course of the study (on Day 1, Day 7, and Day 14), each separated by seven days. On Day 1, participants were familiarized with study procedures, provided informed consent, and completed a questionnaire regarding demographic characteristics at the senior center. On Day 7 (baseline), participants completed a measure of past-week sedentary behavior, received the assigned program in groups of 7-12 people, and completed a questionnaire regarding participants' evaluations of the brief intervention. On Day 14, participants completed a measure of past-week sedentary behavior, participated in group discussions regarding the progress they had made over the past week in changing their behavior, and completed a questionnaire about adverse events experienced as a result of standing or walking over the past week. The first author delivered the interventions for both groups. Study procedures were approved by the local Institutional Review Board.

**Data Analysis**

Frequency counts of participant's response rates and descriptive statistics of participants' ratings of the program and safety issues were calculated and used to determine feasibility, acceptability, and safety, respectively. Efficacy was determined by testing a repeated-measures ANOVA in which the effect of intervention on sedentary behavior across time was compared in
the experimental and control groups. Separate models were tested for weekday, weekend, and weekly sedentary behavior. Additionally, the number of participants sitting ≥ 8 hours per day pre- and post-intervention was examined in both groups and a chi-squared test was performed – a level of behavior associated with reduced risk for mortality and other non-communicable disease (de Rezende et al., 2014; Gennuso et al., 2013).

Results

Senior center and participant flow is documented in Figure 2. All five senior centers approached agreed to participate; however, no older adults volunteered at one senior center. Participants from the remaining four senior centers comprised 42 community-dwelling older adults (n_{experimental} = 25, n_{control} = 17). Participant demographics are summarized in Table 2. Groups did not differ significantly in any of these characteristics (p > 0.05).

At baseline, the experimental group reported less total sedentary behavior (M = 4,808.2 minutes/week, SD = 1,066.5) than the control group (M = 5,477.8 minutes/week, SD = 705.2), t(37) = 2.1, p < .05, d = -0.72. This difference was attributed to the experimental group reporting less weekend day sedentary behavior (655.6 minutes/day, SD = 204.8) than the control group (M = 812.8 minutes/day, SD = 94.3), t(37) = 3.08, p < .05, d = -0.96. Weekday sedentary behavior did not differ between the experimental (M = 699.4 minutes/day, SD = 164.0) and control group (M = 770.7 minutes/day, SD = 115.3), t(37) = 1.58, p = .12, d = -0.32.

Repeated measures ANOVAs revealed significant Group x Time interactions in total sedentary behavior (F[2, 79] = 8.06, p < .001) and weekday sedentary behavior (F[2, 79] = 11.54, p < .001), but not weekend sedentary behavior (F[2, 79] = 0.43, p = .65). Weekday sedentary behavior decreased by an average of 132.6 minutes per day between Day 7 and Day 14 for the experimental group (d = -0.83). Participants in the control group reported a decrease of
only 24 minutes per day of sedentary behavior during that interval ($d = -.16$). A chi-square test revealed no significant relationship between group allocation and the frequency of participants reducing weekday sedentary behavior from more to less than 8 hours per day, $\chi^2 (1, N = 41) = 1.65, p = .19$. Exploratory analyses were conducted with other criteria and the intervention was most effective at reducing the frequency of participants who reported 9+ hours/day of total or weekday sedentary behavior, $\chi^2 (1, N = 41) = 5.06, p = .02$.

Concerning feasibility, 80% of senior centers approached had meaningful recruitment of patrons to participate in the program. Forty-one out of 42 participants (97.6%) attended all three sessions and, overall, participants attended 124 out the possible 126 total sessions (98.4%), indicating a high adherence rate. Out of those 124 observations, 121 observations were complete (97.5%), indicating a high measurement completion rate. Missing observations and incomplete data were limited to the control group.

Regarding acceptability, participants in both groups rated the program highly
(Experimental: $M = 3.5, SD = 0.7$; Control: $M = 3.35, SD=0.4$). The majority of the sample also indicated that they would recommend the program to a family member or friend (Experimental: 88%; Control: 83%). There were no significant differences in ratings of program, or likelihood of recommending between the experimental and control group ($p > .05$).

Safety concerns were rarely reported with the most common adverse event involving mild soreness from standing or walking ($n = 4$). The only other adverse event reported by participants was shortness of breath ($n = 2$). There were no significant differences in frequency of adverse events between the experimental and control group ($p > .05$).
Discussion

This study provided support for the feasibility, acceptability, safety, and preliminary efficacy of a brief group intervention to reduce older adults’ sedentary behavior. Prior to the intervention, the majority of participants in this study reported sitting for at least 11 hours per day – a level of behavior that is greater than national averages for sitting time in this age group as well as a level of behavior associated with significantly greater risk for mortality and non-communicable disease (de Rezende et al., 2014; Gennuso et al., 2013; Harvey, Chastin, & Skelton, 2013; Matthews et al., 2008). In the week following intervention delivery, participants in the experimental group reduced weekday sitting time by approximately 132 minutes per day. This effect was considerably larger than prior sedentary behavior interventions with older adults (Chang et al., 2013; Fitzsimons et al., 2013; Gardiner, Eakin, et al., 2011; King et al., 2013). It is unclear if the level of behavior change seen in this study is sufficient to produce health benefits or reduce health risk in this population.

It is possible that the large behavior change effects in this study may be inflated by the self-report measure of sedentary behavior or demand effects. Further research should evaluate this intervention with an objective measure of behavior and longer follow-up periods similar to previous interventions (i.e. up to 8 weeks). Unlike previous interventions, the present intervention had more success reducing weekday sedentary behavior as opposed to weekend day sedentary behavior (Fitzsimons et al., 2013). Minimal changes in weekend sedentary behavior may be due to the fact that senior centers were not open on weekends and participants felt more compelled to change their behavior at senior centers because that was where the intervention was delivered and they were more likely to be exposed to positive peer influence and support for reducing sedentary behavior.
The large reductions in sedentary time may be attributable to the mode of delivery which combined technology to deliver specialized intervention content (i.e., expert knowledge) with group discussions among peers to help generate ideas for reducing sedentary time and provide social support. Older adults often prefer group settings for exercise (Beauchamp, Carron, McCutcheon, & Harper, 2007; Schutzer & Graves, 2004), and group settings may also be conducive for reducing sedentary behavior.

All senior center managers approached about participating in this study granted permission for the program to be implemented, suggesting that this intervention has high potential for adoption. Potential reach was difficult to ascertain because the number of potential participants at senior centers was not known; however, it was encouraging to find that four of the 5 senior centers had meaningful recruitment. In participating centers, attendance and measurement completion were extremely high, suggesting that participants were interested in the program. Participant’s ratings of the program and its relevance in their daily lives further supported its acceptability. Few adverse events were reported and those events were minor and could be easily be resolved by recommending short bouts of light-intensity activity, such as standing, be incorporated into action plans to reduce sedentary behavior.

In contrast to existing approaches which are delivered by professionals or using smartphones, the present intervention was developed for delivery by paraprofessionals, such as senior center managers or program champions, with limited training about (and financial resources for) sedentary behavior change could deliver this intervention. However, in this study, the intervention was delivered by a content expert so further research is warranted to determine acceptability and efficacy when delivered by paraprofessionals without expert knowledge.
This study had several limitations. The sample in this study largely consisted of White, women who tended to be highly sedentary. Future research should include diverse samples or participants. Self-reported measures of sedentary behavior are known to under-estimate of time spent sitting due to the habitual nature of sitting (Conroy et al., 2013). Future research should include short recall periods of sedentary behavior or incorporate objective measures of sedentary behavior to reduce recall biases (Matthews, Moore, George, Sampson, & Bowles, 2012). This intervention targeted intraindividual determinants of behavior and broader influences on behavior, such as the built environment or social processes, could be incorporated to develop a more comprehensive and effective intervention. Additionally, the small sample size in this study limits confidence in the estimated effect sizes. Finally, as research on this intervention progresses beyond questions about feasibility it will be important to engage center managers and other paraprofessionals – who were originally intended to deliver the intervention – in its delivery. Minimal training for senior center managers would be required; however, senior center managers’ perceptions about facilitating the intervention should be considered in future research.

In conclusion, the brief psychoeducational intervention evaluated in this study capitalizes on widely-available video technology and group discussions to deliver an acceptable and highly efficacious brief intervention to reduce sedentary behavior in older adults. Participants evaluated the intervention favorably, complied with intervention procedures, and had minimal safety issues. This study provides an innovative healthy aging intervention with potential for broad dissemination at limited cost to target a largely-overlooked health threat prevalent in the fastest-growing segment of the population.
References


Memory and Aging Project, a community-based cohort study. *BMC Geriatrics, 10*(77).
doi:10.1186/1471-2318-10-77


doi:10.1207/S15324796ABM2403_04


Table 4.1
Intervention fidelity checklist

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<th>Completely Present</th>
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<tr>
<td>Part I</td>
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<td></td>
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<tr>
<td>Sedentary behavior defined</td>
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<tr>
<td>3+ examples of sedentary behavior provided</td>
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<tr>
<td>Part II</td>
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<td></td>
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<tr>
<td>Normative levels of sedentary behavior (mean hours/day for older adults) reviewed</td>
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<tr>
<td>Participants assessed their current level of sedentary behavior</td>
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<tr>
<td>Participants compared their level of sedentary behavior to normative levels</td>
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<tr>
<td>Part III</td>
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<tr>
<td>5+ physiological and psychological consequences of sedentary behavior described</td>
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<tr>
<td>5+ physiological and psychological benefits of alternative behavior (e.g., standing, walking) described</td>
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<tr>
<td>Group discussion about consequences and benefits described</td>
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<tr>
<td>Part IV</td>
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<tr>
<td>Action planning defined</td>
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<tr>
<td>Participants identified times when they engage in excessive amounts of sedentary behavior</td>
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<tr>
<td>Participants identified times when they interrupt sedentary behavior by engaging in alternative behavior</td>
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<tr>
<td>Participants provided with 3+ example action plans (specifying when, where, and how)</td>
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<tr>
<td>Participants developed three action plans for the upcoming week</td>
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<tr>
<td>Participants shared their action plans with the group</td>
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<td>Part V</td>
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<tr>
<td>Target behavior goals reviewed</td>
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Note. It may be beneficial to add an additional column in this tablet to record any observations when delivering the intervention content.
Table 4.2
Demographic characteristics of the sample

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<th>SD</th>
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<td>Sex (%)</td>
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<td>Income (%)</td>
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<td>$5,000-19,999</td>
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<tr>
<td>Marital Status (%)</td>
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<td>Housing (%)</td>
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<tr>
<td>Assisted living community</td>
<td>9.3</td>
<td></td>
<td></td>
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<tr>
<td>Other</td>
<td>9.3</td>
<td></td>
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<tr>
<td>Living Arrangement (%)</td>
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<tr>
<td>Spouse/Partner</td>
<td>16.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Child/ren</td>
<td>9.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grandchild/ren</td>
<td>2.3</td>
<td></td>
<td></td>
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<tr>
<td>Other family members</td>
<td>2.3</td>
<td></td>
<td></td>
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<tr>
<td>Other non-relatives</td>
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<tr>
<td>Pet/animal companion</td>
<td>4.7</td>
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<tr>
<td>Alone</td>
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<tr>
<td>Other</td>
<td>2.3</td>
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*Note.* 42 participants supplied demographic information on Day 1.
Figure Captions

Figure 4.1. Dual-process framework used to inform the intervention

Figure 4.2. CONSORT diagram showing flow of participants through each stage of the study
Chapter V: Conclusions
This dissertation established relations between motivation, sedentary behavior, and well-being in older adults to inform intervention development. The major conclusions from this project were that (1) older adults’ sedentary behavior is regulated by both controlled and automatic motivational processes, (2) both between-person processes and within-person motivational processes were associated with sedentary behavior, (3) sedentary behavior and life satisfaction were linked through within-person processes, (4) older adults found the psychoeducational intervention approach to be engaging and indicated that they would recommend such a program to their friends and family members, and (5) the intervention also reduced older adults’ self-reported weekday sedentary behavior in the week following the delivery of the intervention by approximately two hours more per day compared to the control group. Ultimately, these results can inform the development of interventions to reduce older adults’ sedentary behavior and promote healthy and successful aging.

This dissertation provided the first evidence that older adults’ sedentary behavior is regulated by dual motivational processes. Previous interventions to reduce older adults’ sedentary behavior have targeted controlled regulatory processes, such as intentions, attitudes, or task beliefs, exclusively (Chang, Fritschi, & Kim, 2013; Fitzsimons et al., 2013; Gardiner, Eakin, Healy, & Owen, 2011; King et al., 2013). These interventions have overlooked an important aspect of behavior regulation, namely automatic processes such as habit strength for sitting. Taken together with previous research (Conroy, Maher, Elavsky, Hyde, & Doerksen, 2013), this dissertation supports proposals that health behaviors like sedentary behavior are the result of both controlled and automatic regulatory processes (Sheeran, Gollwitzer, & Bargh, 2013). Interventions attempting to reduce older adults’ sedentary behavior should incorporate
intervention content that focuses on disrupting sitting habits and creating new habits that align with behavioral goals (e.g., habits to engage in light-intensity physical activity).

This dissertation also established the first evidence that controlled motivational processes contribute to older adults’ sedentary behavior at both the between- and within-person levels. Considering that planning and other controlled motivational constructs (i.e., task self-efficacy and intentions to limit sedentary behavior) observed in this dissertation varied significantly from day to day, this finding suggests that interventions may be more effective at reducing daily sedentary behavior if they are sensitive to this daily motivational variation. Therefore interventions aiming to reduce older adults’ sedentary behavior via controlled motivational processes should focus on having participants, for example, develop stronger action and coping plans on a daily basis (at least for days when sedentary behavior is expected to be high).

This dissertation also elaborated on associations between sedentary behavior, physical activity, and life satisfaction in older adults. Associations differed between objective and self-reported measures of behavior. The objective measure of sedentary behavior employed in these dissertation studies provided more accurate estimates of sedentary behavior than self-reports because the ActivPAL3™ activity monitor relies on inclinometer and accelerometer data to determine time spent sitting, standing, or moving. Therefore this type of objective monitor can provide a clearer picture of associations between sedentary behavior, physical activity, and life satisfaction. Self-report measures of health behaviors are likely to be influenced by the extent to which older adults’ time use aligns with their values, interests, goals, and level of stimulation during activities and may distort associations between these health behaviors and life satisfaction. Results suggest that daily changes in sedentary behavior and perceived physical activity can have implications for older adults’ well-being. Interventions designed to enhance
well-being and quality of life in older adults should consider targeting daily changes in total sedentary behavior and daily changes in the volume or intensity of physical activity. These small changes are likely more manageable and easier to incorporate into and sustain in daily life.

Finally, this dissertation culminated with the development and preliminary evaluation of a brief psychoeducational intervention that was informed by results reported in Chapter II of this dissertation. This intervention capitalized on widely-available technology, video, and group discussions to deliver an acceptable and efficacious brief intervention to reduce sedentary behavior in older adults. Participants evaluated the intervention favorably, complied with intervention procedures, and had minimal safety issues. Innovative healthy aging interventions, like the one evaluated in this dissertation, with potential for broad dissemination at limited cost are needed to target a largely-overlooked health threat prevalent in the fastest-growing segment of the population and promote well-being.

Older adults spend more than 60% of their waking hours each day sitting – the most out of any segment of the population (Harvey, Chastin, & Skelton, 2014; Matthews et al., 2008). This level of behavior puts older adults at increased risk for the negative health consequences associated with sedentary behavior. Accumulating evidence links excessive sitting, independent of physical activity, with increased risk for all-cause mortality and non-communicable diseases, poor physical and cognitive functioning, and reduced well-being (Biswas et al., 2015; Blodgett, Theou, Kirkland, Andreou, & Rockwood, 2015; de Rezende, Rey-López, Matsudo, & do Carmo Luiz, 2014; Gennuso, Gangnon, Matthews, Thraen-Borowski, & Colbert, 2013).

Interventions designed to reduce sedentary behavior by displacing sedentary behavior with light-intensity physical activity (e.g., standing, slow walking) represent a promising way to promote active lifestyles in older adults (Smith, Ekelund, & Hamer, 2015; Sparling, Howard,
Dunstan, & Owen, 2015). Displacing sedentary behavior with light-intensity physical activity removes many commonly-cited barriers to engaging in moderate- or vigorous-intensity physical activity (Brawley, Rejeski, & King, 2003; Lunt et al., 2014). Reallocating time spent in sedentary pursuits to light-intensity physical activity has also been associated with improvements in health in adults and older adults including improved cardiovascular functioning, glucose metabolism, and physical functioning (Buman et al., 2010, 2013; Dunstan et al., 2012).

Enhancing health profiles is necessary to promote healthy and successful aging in our graying society (Rowe & Kahn, 1997). As people continue to live longer in our society, there has been an increased emphasis on experiencing the best old age possible; suggesting that years added to life should be quality years (Pruchno, 2015). Targeting a high volume, largely overlooked health behavior, like sedentary behavior, appears to be a viable option for adding quality years in old age.

Today there are more than 43 million older adults living in the United States and that number is expected to nearly double by 2050 (Centers for Disease Control and Prevention, 2013). In 2050, older adults will make up more than 20% of the population. Over the next 35 years, as our society continues to gray, healthy aging interventions will become even more paramount as a way to combat the costs associated with the treatment and care of older adults.

Limitations, Future Directions, and Conclusion

Some important limitations of this dissertation should be addressed in future research. One such limitation is that these dissertation studies consisted of samples of mostly White, non-Hispanic, relatively healthy older adults. Sedentary behavior has been shown to systematically vary as a function of race, ethnicity, health status, and age (Gennuso et al., 2013; Matthews et al.,
2008; Seguin et al., 2014). Therefore future research is necessary to investigate if the regulation and consequences of sedentary behavior differ as a function of these demographics.

Furthermore, this dissertation investigated the factors that regulated, the psychological consequences associated with, and the acceptability and efficacy of a community-based intervention designed to limit or reduce sedentary behavior. However, a target behavior like increasing the frequency or duration of bouts of standing throughout the day may be regulated by different motivational processes, have unique implications for older adults’ health and well-being, and require different intervention content to effectively change behavior (Buman et al., 2010, 2013; Dunstan et al., 2012). Developing target behavioral goals that are approach-based (i.e., incorporating bouts of standing to take breaks form sitting) may ultimately be more effective for changing behavior than goals that are avoidance-based (i.e., limiting sedentary behavior to 8 hours/day; Mann, de Ridder, & Fujita, 2013). Future research should focus on understanding and predicting bouts of standing as well as sedentary behavior.

The automatic motivational processes targeted in this dissertation focused exclusively on habits. It is unclear what the cues are that lead older adults’ to engage in habitual sedentary behavior. Identifying these cues can inform future interventions to reduce sedentary behavior (e.g., by modifying specific features of the built environment that promote sedentary behavior). Additionally, future research investigating other automatic regulatory processes, such as automatic evaluations, self-beliefs, self-schemas, or goals, will further add to our understanding of the automatic regulation of sedentary behavior. Integrating techniques that target these automatic regulatory processes into sedentary behavior intervention efforts is an important next step for future research.
This dissertation also focused exclusively on the intraindividual factors regulating behavior. While identifying the controlled and automatic motivational processes that regulate sedentary behavior is important because it highlights ways in which existing intervention content can be modified (e.g., reducing emphasis on health outcomes associated with behavior, increasing emphasis on developing daily efficacy and action plans to limit sedentary behavior), other influences on behavior should also be considered in future research. Influences that extend beyond the individual, such as peer and familial influences as well as the influence of the built environment and the culture and policies of organizations or communities likely also contribute to sedentary behavior (Otten, Jones, Littenberg, & Harvey-Berino, 2009). Future research should approach understanding sedentary behavior from an ecological perspective and investigate influences on behavior beyond the individual (Owen, Healy, Matthews, & Dunstan, 2010). Understanding these types of broad influences on behavior is also likely to contribute to the maintenance of behavior change. Although the maintenance of reductions in sedentary behavior is relatively unexplored, ecological frameworks would suggest that an intervention that targets determinants at multiple levels within such a framework would have the greatest potential for initiating and sustaining behavior change (Bopp & Kaczynski, 2010; McLeroy, Bibeau, Steckler, & Glanz, 1988). One such example of a multilevel approach would be an intervention that incorporates (1) daily action planning to assist in the breaking of counter-intentional habits and the formation of good habits, (2) the addition of high top tables to provide an alternative to sitting, and (3) changes to senior center programming that incorporate more bouts of standing in center activities. Ultimately, determining the relative influence, as well as potential interactions, of these levels will inform intervention content and result in interventions that have the greatest potential for lasting behavior change.
Although this dissertation established relations between sedentary behavior and life satisfaction and attempted to modify older adults’ sedentary behavior, it did not investigate the amount of behavior change necessary to produce clinically-meaningful improvements in health or well-being. Establishing the minimal reductions in sedentary behavior necessary to improve health and well-being will be important for developing target behavioral goals for future interventions.

In closing, sedentary behavior is a high volume, largely overlooked health behavior in our society and represents a viable behavior change target to promote healthy and successful aging. This dissertation informed the development of interventions designed to reduce older adults’ sedentary behavior. This dissertation also identified suitable motivational targets for interventions within a dual-process framework. Knowing these targets will enhance the effectiveness of interventions designed to reduce older adults’ sedentary behavior. Additionally, this dissertation established that small changes in daily sedentary behavior have implications for life satisfaction - an important indicator of well-being and successful aging in older adults. Finally, this dissertation identified an innovative healthy aging intervention with potential for broad dissemination at limited cost to target a largely-overlooked health threat prevalent in the fastest-growing segment of the population. Prioritizing healthy aging interventions of this nature may improve the quality of life for older adults and reduce health care costs associated with treatment and management of chronic diseases.
References


randomized controlled trial. *Archives of Internal Medicine, 169*(22), 2109–2115.

http://doi.org/10.1001/archinternmed.2009.430


http://doi.org/10.1016/j.amepre.2013.10.021


http://doi.org/10.1007/s40279-015-0310-2

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