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A daily process analysis of physical activity, sedentary behavior, and perceived cognitive abilities

Patrick T. Fitzsimmons [a], Jaclyn P. Maher [a], Shawna E. Doerksen [b], Steriani Elavsky [a], Amanda L. Rebar [a], David E. Conroy [c,*]

[a] Department of Kinesiology, The Pennsylvania State University, United States
[b] Department of Recreation, Park & Tourism Management, The Pennsylvania State University, United States
[c] Department of Preventive Medicine, Center for Behavior & Health, Northwestern University, Chicago, IL, United States

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ABSTRACT

Objectives: This study evaluated the role of both physical activity and sedentary behavior in daily perceptions of cognitive abilities and whether these relations exist within-person, between-person, or both.
Design: Non-experimental, intensive longitudinal research using ecological momentary assessments.
Method: College students wore accelerometers and provided end-of-day reports on physical activity, sedentary behavior, and perceived cognitive abilities for 14 days.
Results: Across self-reports and objective measures of behavior, daily deviations in physical activity were positively associated with perceived cognitive abilities. Daily deviations in self-reported, but not objectively-assessed, sedentary behavior also were negatively associated with perceived cognitive abilities. Contrary to previous research, overall levels of physical activity and sedentary behaviors were not associated with perceived cognitive abilities.
Conclusions: These findings indicate that physical activity has a within- rather than between-person association with perceived cognitive abilities although between-person associations effects may require longer monitoring periods to manifest. Further research is needed to establish the direction of causality and resolve whether the nature (rather than quantity) of sedentary activities influences cognition.

Physical activity offers many mental health benefits including enhanced executive functioning (Ahn & Fedewa, 2011; Colcombe & Kramer, 2003). These benefits for executive function have been documented across the lifespan with the greatest evidence at the young and old extremes (Guiney & Machado, 2013); however, little is known about how sedentary behavior affects executive function. Given that sedentary behavior has distinct physical health consequences from insufficient levels of physical activity (Owen, Healy, Matthews, & Dunstan, 2010), it may also have distinct consequences for cognitive performance. In this study, we focused on perceived cognitive abilities because perceptible daily fluctuations in cognitive performance are important and clinically-meaningful outcomes. Moreover, if linked with physical activity or sedentary behavior, those perceptions may influence emerging outcome expectations for those behaviors. This study also builds on the fact that previous research has focused on identifying *who* differs cognitively (e.g., people who are more vs. less fit or more vs. less active) and less is known about *when* such differences exist or *why*. Information about the dynamics of health behaviors, such as physical activity or sedentary behavior, and cognition may lead to improved strategies for improving cognition as well as a clearer understanding of the consequences of health behaviors.

Cognition and physical activity in daily life

Cognition refers to how people process sensory information and includes a number of functions, such as attention, memory, and reasoning, which are required for daily activities (Neisser, 1967). These abilities develop from birth and tend to diminish in older adulthood (Hillman et al., 2006; Strout & Howard, 2012). Although cognitive development is often viewed as a slow-changing process over extended time periods, day-to-day fluctuations in cognition occur and may influence one's ability to complete daily tasks (Neupert, Almeida, Mroczek, & Spiro, 2006). These day-to-day

* Corresponding author. Department of Preventive Medicine, Center for Behavior & Health, Northwestern University, Chicago, IL, United States.
E-mail address: conroy@psu.edu (D.E. Conroy).

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shifts in cognition have been linked to daily fluctuations in affect and stress but not to specific behavioral antecedents (Brose, Schmiedek, Lövdén, & Lindenberger, 2012; Neupert et al., 2006). Physical activity also varies on a daily basis (Behrens & Dinger, 2003, 2005; Conroy, Elavsky, Hyde, & Doerksen, 2011; Conroy, Elavsky, Maher, & Doerksen, 2013) and has been linked with daily affect and stress (Gerber et al., 2013; Hyde, Conroy, Pincus, & Ram, 2011) so it is plausible that fluctuations in physical activity may influence day-to-day cognitive performance.

A positive association between physical activity and cognition has been documented in numerous studies contrasting high and low fit people as well as more and less active people (Guiney & Machado, 2013; Hillman, Buck, Themanson, Pontifex, & Castelli, 2009). In these studies, cognition has frequently been operationalized in terms of specific executive functions (e.g., attention, inhibition, task switching, working memory) or general academic achievement (Carlson et al., 2008; Castelli, Hillman, Buck, & Erwin, 2007; Coe, Pivarnik, Womack, Reeves, & Malina, 2006; McNaughten & Gabbard, 1993; Ruscheweyh et al., 2011; Wu et al., 2011). Although neurocognitive and performance-based measures are considered gold standards for assessing cognition, self-reports of perceived cognitive abilities have been linked with performance on a variety of measures of cognitive function (e.g., learning, memory, processing speed, flexibility; Becker, Stuifbergen, & Morrison, 2012; Benedict et al., 2003). Moreover, assessing patient-reported outcomes, such as self-reported cognitive abilities, informs understanding of a person's perceived capabilities, limitations and needs, and can drive help-seeking behavior and openness to intervention (Centers for Disease Control and Prevention, 2000; Donaldson, 2008; Greenhalgh, 2009). Even small fluctuations in these perceptions over time may reveal clinically-meaningful changes in individual functioning because these measures center on the person's experience (Deshpande, Rajan, Sudeepthi, & Abdul Nazir, 2011). From a motivational standpoint, perceived cognitive abilities provide a basis for individuals to form outcome expectations for antecedent behaviors. To the best of our knowledge, none of the studies cited above have sampled cognition intensively over time so this study was designed to focus on the dynamics of perceived cognitive abilities and establish links with putative behavioral antecedents.

The extant literature has emphasized between-person differences in physical activity and cognition that are presumably mediated by adaptations in brain volume, cerebral blood flow, and cerebrovascular reserve (Colcombe et al., 2006; Davenport, Hogan, Eskes, Longman, & Poulin, 2012; Erickson et al., 2009; Voss, Carr, Clark, & Weng, 2014). These mechanisms reflect both long- and short-term adaptations to physical activity so it is possible that the effects of physical activity on cognition may reflect differences in people's overall physical activity, daily physical activity, or both. It is also possible that the mechanisms linking physical activity and cognition are age-dependent. Overall physical activity (as a precursor of fitness) may be most valuable for stemming age-related decline in older adults (Colcombe & Kramer, 2003). In contrast, most college students are emerging or young adults and have experienced limited age-related cognitive or vascular decline. For this population, overall physical activity levels may not impact brain volume or cerebrovascular reserve substantially, and one might anticipate that any cognitive effects would be derived from daily physical activity which impacts cerebral blood flow directly. Before investigating any of the proposed psychological or physiological mechanisms, it is necessary to evaluate whether perceived cognitive abilities are linked with overall physical activity (reflecting a between-person process), daily physical activity (reflecting a within-person process), or both.

Sedentary behavior and cognition

The aforementioned research focused on physical activity and largely neglected the potential confound of sedentary behavior. Whereas physical activity refers to any bodily movement produced by skeletal muscle that requires energy expenditure, sedentary behavior refers to activities that do not increase energy expenditure substantially above the resting level (e.g., sitting, lying down, watching television; Caspersen, Powell, & Christenson, 1985; Sedentary Behaviour Research Network, 2012). This distinction between physical activity and sedentary behavior is critical for two reasons. First, sedentary behavior can displace physical activity and confound interpretations of associations between physical activity and cognitive abilities. Only by differentiating these behaviors is it possible to evaluate whether the observed link is due to insufficient physical activity or excessive sedentary behavior. Likewise, differentiating between these behaviors can inform theorizing about possible mechanisms (e.g., increased vs. decreased cerebral blood flow). Second, many health consequences of insufficient physical activity and excessive sedentary behavior are independent and additive (Owen et al., 2010; Thorp, Owen, Neuhaus, & Dunstan, 2011) so it is possible that each behavior has a unique effect on cognitive abilities. If relations are due to a single behavior, future interventions should focus on that behavior alone. In contrast, independent additive relations would imply that multiple health behaviors should be changed to improve cognitive abilities maximally.

Findings on sedentary behavior and cognition have been limited and mixed (for a review, see Voss et al., 2014). In a sample of older adults, computer usage was positively associated with executive function, but television watching was negatively associated with executive function (Kesse-Guyot et al., 2012). Another study indicated that directly-measured sedentary behavior was not associated with children's academic performance but self-reported sitting time was positively associated (Syväoja et al., 2013). Worksite interventions that use standing or treadmill workstations to reduce sitting time have shown no adverse effects on employees' cognition; however those findings can be difficult to interpret because standing and physical activity are often confounded (Alderman, Olson, & Mattina, in press; Ohlinger, Horn, Berg, & Cox, 2011). Based on the limited available literature, we hypothesized that sitting time (which is not differentiated by the type of task) would be associated with lower perceived cognitive abilities.

The present study

This study was designed to fill two key gaps in the literature. First, we sought to extend research establishing between-person associations between physical activity and cognition by examining whether fluctuating levels of physical activity also have within-person associations with daily cognitive abilities. Second, we sought to evaluate both between- and within-person links between sedentary behavior and daily cognitive abilities. To assess cognitive abilities and behavior in the natural context of people's daily lives, we used an ecological momentary assessment research design with self-reports of daily cognitive abilities at the end of each day serving as our primary outcome. Behavior was measured using both self-report and direct measures of physical activity and sedentary behavior. In the absence of literature on within-person associations between these behaviors and cognition, our hypotheses were identical for the between- and within-person levels of analysis. Specifically, physical activity and sedentary behavior were expected to exhibit positive and negative associations, respectively, with daily cognitive abilities. We also conducted exploratory