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Perceived Control and Cognition in Adulthood: The Mediating Role of Physical Activity

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The cognitive benefits of a greater sense of control are well-established; however, only recently have the mechanisms involved in this relationship been explored. Because of its well-established cognitive benefits and positive relationship to perceived control, physical activity has been suggested as a potential mediator. However, with age, not only does cognition tend to decline, but so does one's perception of control and their level of physical activity. Therefore, it is important to understand the relationship between these variables from a life span perspective. The goal of the current study was to expand on past work that investigated physical activity as a mediator between perceived control and change in cognition across 4 years to a multi-decade perspective that examines these variables as they change from midlife to older adulthood. To do so, we used longitudinal data across 20 years from the Midlife in the United States Study. Our results show that perceiving more control over one's life predicted less decline in cognition 20 years later, and this relationship was mediated by an increase in physical activity. We consider limitations and future directions to further our understanding of the role of physical activity in the relationship between perceived control and cognitive aging.

Keywords: control beliefs, physical activity, cognition, life span development, latent change

There is an abundance of evidence that perceiving greater control over your life is associated with key aging outcomes, including cognition (Lachman, 2006). Perceived control has been linked to enhanced cognitive health, however only recently have the mechanisms involved in these relationships been explored (Lachman, 2006). One proposed mechanism is physical activity (Infurna & Gerstorf, 2013). Given that physical activity declines with age (Centers for Disease Control and Prevention [CDC], 2013), it is important to explore its antecedents and consequences. Although perceived control (Lachman, Agrigoroaei, & Rickenbach, 2015) and cognitive health (Salthouse, 2009) also decline on average in later life, there are individual differences and there is evidence these factors can be modified. The goal of this study is to further explore the relationship between sense of control, physical activity, and cognition throughout adulthood.

Age and Perceived Control

Perceived control is typically considered to be a product of one's view of the self and environment as opposed to a set personality trait. Although some evidence suggests that perceived control tends to peak in midlife and then decline into older adulthood (Mirowsky & Ross, 2007), the general pattern appears to be that control beliefs decline with aging (Hooker & McAdams, 2003) suggesting that older adults feel more vulnerable in terms of their ability to control outcomes involving their health (Lachman, 2006). This pattern of decline is perhaps expected due to the increase in losses and decrease in gains associated with aging, and that these changes are frequently uncontrollable (Lachman, Neupert, & Agrigoroaei, 2011). In fact, one's level of perceived control may become more important as we age. It tends to be a stronger predictor of outcomes related to successful aging, such as health. For example, Lachman and Agrigoroaei (2010) found that the age-related declines in functional health were attenuated by one's level of perceived control, among other protective factors such as social support and physical activity.

Cognitive Benefits of Perceived Control

A greater sense of control has been associated with enhanced cognitive performance including better memory performance (Windsor & Anstey, 2010), greater strategy use (Lachman & Andreoletti, 2006), and greater effectiveness of cognitive training (Rebok, Rasmusson, & Brandt, 1996; Wolinsky et al., 2010). In

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fact, recent findings from the Advanced Cognitive Training for Independent and Vital Elderly study suggested that one's locus of control could be a factor in understanding why some are at greater risk for developing cognitive impairment (Zahodne et al., 2015). Additionally, those with a greater sense of control are less likely to show age-related declines in cognitive functioning (Caplan & Schooler, 2003; Infurna & Gerstorf, 2013).

Indeed, as is true for other health outcomes noted above, one's level of perceived control may be even more important for one's level of cognition with increasing age. There have been mixed results as to whether or not the relationship between control beliefs and cognition are age-dependent. For example, Lachman and Agrigoroaei (2012) explored anxiety as a mechanism between control beliefs and cognition and did not find that the relationship between control beliefs and cognition was moderated by age in a life span sample aged 22 to 84. Similarly, Infurna and Gerstorf (2013) did not find age-dependent effects when examining physical activity as a mechanism between perceived control and cognition across 4 years. In contrast, the relationship between control beliefs and memory was found to be greater for middle-aged and older adults than for younger adults in another study (Lachman, 2006).

Mechanisms

The directionality of the relationship between control beliefs and (physical, cognitive, and psychological) health has been debated for quite some time. Some of the most promising work from longitudinal studies shows that perceived control does have an influence on important outcomes such as health and longevity (Infurna, Ram, & Gerstorf, 2013; Turiano, Chapman, Agrigoroaei, Infurna, & Lachman, 2014). Nevertheless, the evidence also suggests that the relationship is reciprocal; beliefs not only affect health, but changes in health in turn influence beliefs about control (Infurna & Okun, 2015).

Soederberg-Miller and Lachman (1999) proposed a conceptual model, updated by Robinson and Lachman in 2016, concerning some of the possible mechanisms linking control beliefs and performance, as well as potential mediators. Control beliefs are believed to influence outcomes and performance through behavior (e.g., strategy use), physiology (e.g., anxiety, stress), motivation (e.g., effort), or affect (e.g., depression). This model, derived from social learning theory (Bandura, 1997), assumes the processes to be reciprocal and cyclic such that the outcomes (e.g., memory, physical declines, well-being) may impact one's control beliefs, self-efficacy, and feelings of mastery, or beliefs about one's abilities, and/or constraints, which in turn can impact possible behavioral or physiological mediators as well as future outcomes (Bandura, 1997; Soederberg-Miller & Lachman, 1999).

For example, older adults who are experiencing trouble with their memory or physical ability may react with a decreased sense of control in these domains, especially if the difficulties can be attributed to uncontrollable factors (e.g., age, injury). This lowered sense of control can be harmful if it is associated with increased stress, anxiety, or inactivity (Agrigoroaei & Lachman, 2011). In sum, perceived control and related behaviors seem to be involved in a multidirectional, reciprocal relationship wherein perceived control is both a predictor and outcome of age-related changes such as memory (Lachman, Weaver, Bandura, Elliott, & Lewkowicz, 1992; Soederberg-Miller & Lachman, 1999) and health (Skaff, 2007).

Physical Activity

Conceptual models of perceived control outline that physical activity may underlie why perceived control is protective against cognitive health (Lachman et al., 2011; Rodin, 1986; Uchino, 2006). For example, perceiving more control is related to engaging in health-promoting behaviors and exhibiting better health profiles (Infurna & Gerstorf, 2013; Lachman & Firth, 2004; White, Wójcicki, & McAuley, 2012), which in turn influence cognitive health. The cognitive benefits of physical activity are well-documented across the life span, with support for every age group from children to older adults (for review see Erickson, Hillman, & Kramer, 2015). However, as older adults typically experience the most significant cognitive deficits (Salthouse, 2009), physical activity may be even more beneficial for them. Past work has found cognitive benefits from both light intensity activity, such as leisurely walking, and higher intensity aerobic activity (Colcombe et al., 2004; Erickson et al., 2015). Within the cognitive domain, there is evidence for exercise-related improvements for both executive functioning (e.g., processing speed; Frederiksen et al., 2015) and memory (e.g., spatial/episodic memory; Erickson et al., 2011). However, there is some evidence to suggest that these functions are distinctly influenced by physical activity, where processes that require executive control, in contrast to memory, tend to exhibit more robust findings (Kramer et al., 1999; Smith et al., 2010).

As such, physical activity may act as a mediator linking perceived control and cognition. If one feels more in control he or she would be more likely to engage in positive health behaviors such as physical activity, and subsequently would reap the benefits of physical activity such as enhanced cognitive performance. Examining physical activity as an underlying factor will afford a preliminary understanding of plausible mechanisms for the relationship between perceived control and health outcomes, including cognition. Furthermore, examining whether change in a mediator such as physical activity affects the relationship between perceived control and cognition has the potential to shed light onto how mediation processes progress with time. Ultimately, this examination will further our knowledge of personalized prevention and intervention programs so as to protect against or minimize declines (Robinson & Lachman, 2016; Spiro & Brady, 2011).

Current Study

Consistent with Lachman's integrative model of perceived control (Lachman, 2006; Lachman et al., 2011), empirical evidence suggests that higher levels of perceived control are directly associated with higher levels of physical activity (Infurna & Gerstorf, 2013; Roepke & Grant, 2011; White, Wójcicki, & McAuley, 2011) and that higher levels of physical activity have a positive influence on cognition (Lachman & Firth, 2004; Spiro & Brady, 2011; Stampfer, 2006). Such studies, however, have typically focused only on one of these underlying factors and primarily used data obtained at one time point. Infurna and Gerstorf (2013) furthered this work by simultaneously testing these underlying factors and exploring their relationship longitudinally. Specifically, they examined physical activity as a mediating factor in the relationship between perceived control and episodic memory. Using data from the Health and Retirement Study, Infurna and Gerstorf (2013) found that levels of and 2-year changes in physical activity mediated the relationship between perceived control and memory change. These findings illustrate that perceived control and physical activity influence changes in memory. Additionally, these findings set the precedent for continued exploration in this topic. Specifically, does physical activity mediate the relationship between other control–cognition associations (e.g., executive functioning)? Additionally, it is important to expand this investigation of longitudinal mediation to longer time spans: how do these relationships change across adulthood, and how do they transition from midlife to older adulthood? This is particularly necessary due to the fluctuating life span trajectory of perceived control, physical activity, and cognition. Therefore, the objective of the current study was to extend previous work identifying physical activity, and changes in level of physical activity, as a mediating factor between perceived control and cognition (both episodic memory and executive functioning) across 20 years' time.

This study used data from the Midlife in United States study (MIDUS), a nationally representative sample of middle-aged and older adults with data on multiple behavior and psychological health factors. We examined whether changes in control predicted changes in physical activity and cognition. Indirect effects were estimated from perceived control to cognition 20 years later through physical activity. Specifically, we hypothesized that initial level of, and change in perceived control would predict change in cognition, and that this relationship would be mediated by change in physical activity.

Method

Participants

This study was approved by the participating universities' institutional review boards. Participants were community-dwelling adults from the MIDUS, which was conducted at three time periods. Wave 1 data were collected in 1995 and 1996 through random digit dialing (RDD) of U.S. households with at least one telephone in the contiguous 48 states, stratified by age with an oversample of those between 40 and 60 years of age (Brim, Ryff, & Kessler, 2004). The participants ranged in age from 24 to 75 years (M = 46.40, SD = 13.00). The overall response rate was 70% for the telephone interview. Wave 2 data were collected in 2004 and 2005 and consisted of 4,955 adults aged 32 to 84 years, which is approximately 75% of the original sample, adjusted for mortality (Brim et al., 2004). Wave 3 data collection spanned from 2013 to 2014. Of the sample from Wave 2, 76.9% of those eligible (N = 3,294) were retested, with a completion rate of 82% (N = 2,693) of the eligible participants. Wave 3 ranges in age from 42 to 92 years (M = 64.30, SD = 11.2). Descriptive statistics for covariates and all observed variables can be found in Table 1 and bivariate Pearson correlations for covariates and all latent variables are displayed in Table 2. At Wave 1, 52.53% of participants were female, ages 20 to 75 (M = 46.77, SD = 12.92). Participants were fairly well-educated, with 16% reporting at least a 4-year college degree. Average functional health at wave 1 was 3.60 (SD = 0.67).

Measures

Covariates. Consistent with Infurna and Gerstorf's (2013) models, we included age as a covariate to examine the predicted relationships irrespective of age. Age was calculated by subtracting the testing date from the participant's birthdate. We also included gender, education, and functional health as covariates. Gender was measured via self-report and coded as a dummy variable. Years of educational attainment was determined with a categorical measure of level of education from 1 (*no school/some grade school*) to 12 (*PhD, EdD, MD, DDS, LLB, LLD, JD, or other professional degree*), which was treated as an ordinal variable in analyses. Functional health was measured with seven items from the Physical Functioning subscale from the SF-36 Health Survey (Ware & Sherbourne, 1992). The seven items capture the

Table 1
Descriptive Statistics for All Study Variables

Variable	Wave 1		Wave 2		Wave 3	
	M (SD)	Min–Max	M (SD)	Min–Max	M (SD)	Min–Max
Age	46.77 (12.92)	20–75	55.99 (12.33)	28–84	64.01 (11.36)	42–93
Gender	52.35% Female		54.2% Female		55.8% Female	
Education	6.84 (2.49)	1–12	7.26 (2.52)	1–12	7.55 (2.52)	1–12
Functional health	3.61 (.66)	1–4	3.44 (.77)	1–4	3.27 (.86)	1–4
Perceived control	5.59 (.95)	1–7	5.58 (.96)	1.13–7		
Constraints	5.35 (1.25)	1–7	5.42 (1.18)	1.00–7.00		
Personal mastery	5.84 (1.01)	1–7	5.74 (1.03)	1.00–7.00		
Activity			4.99 (1.04)	1.00–6.00	5.08 (1.01)	1–6
Episodic memory			.00 (1.00)	−3.07–3.83	−.02 (1.03)	−3.07–3.83
Word list immediate			6.72 (2.29)	.00–15.00	6.72 (2.36)	.00–15.00
Word list delayed			4.42 (2.61)	.00–14.00	4.40 (2.67)	.00–14.00
Executive functioning			.00 (1.00)	−4.74–3.42	−.24 (1.08)	−5.28–2.97
Digits backwards			5.01 (1.51)	.00–8.00	4.98 (1.46)	.00–8.00
Category fluency			18.77 (6.15)	.00–42.00	18.85 (6.06)	.00–40.00
Number series			2.33 (1.61)	.00–8.00	2.50 (1.78)	−3.88–3.09
Backwards counting			37.30 (11.43)	−2.00–100.00	36.39 (11.46)	−2.00–90.00
Stop–Go switch task			−1.07 (.21)	−2.57–.61	−1.26 (.35)	−7.56–2.42

Note. Minimum (Min) and maximum (Max) values represent range of data. Episodic memory and executive functioning scores represent standardized composite values where Wave 3 was standardized on the basis of Wave 2 values.

Table 2
Descriptive Statistics and Pearson Bivariate Correlations Coefficients Between All Covariates and Model Constructs

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Age	—											
2. Gender	.02	—										
3. Education	$-.10^{**}$	$-.10^{**}$	—									
4. Health	$-.25^{**}$	$-.12^{**}$	$.22^{**}$	—								
5. Control_1	$-.10^{**}$	$-.08^{**}$	$.15^{**}$	$.25^{**}$	—							
6. Control_2	$-.06^{**}$	$-.08^{**}$	$.15^{**}$	$.23^{**}$	$.58^{**}$	—						
7. Activity_2	$-.23^{**}$	$-.07^{**}$	$.18^{**}$	$.15^{**}$	$.11^{**}$	$.12^{**}$	—					
8. Activity_3	$-.24^{**}$	$-.08^{**}$	$.16^{**}$	$.20^{**}$	$.11^{**}$	$.11^{**}$	$.35^{**}$	—				
9. EM_2	$-.34^{**}$	$.22^{**}$	$.21^{**}$	$.15^{**}$	$.09^{**}$	$.10^{**}$	$.14^{**}$	$.10^{**}$	—			
10. EM_3	$-.38^{**}$	$.24^{**}$	$.16^{**}$	$.13^{**}$	$.09^{*}$	$.06^{**}$	$.13^{**}$	$.13^{**}$	$.54^{**}$	—		
11. EF_2	$-.43^{**}$	$-.11^{**}$	$.41^{**}$	$.25^{**}$	$.13^{**}$	$.15^{**}$	$.24^{**}$	$.17^{**}$	$.43^{**}$	$.36^{**}$	—	
12. EF_3	$-.46^{**}$	$-.11^{**}$	$.34^{**}$	$.20^{**}$	$.11^{**}$	$.07^{**}$	$.18^{**}$	$.22^{**}$	$.32^{**}$	$.41^{**}$	$.76^{**}$	—

Note. Subscripts indicate wave of data collection. EM = episodic memory; EF = executive functioning.
$^{*}p < .05$. $^{**}p < .01$.

extent to which the participants' health level limits them in doing different activities: lifting or carrying groceries; bathing or dressing; climbing several flights of stairs; bending, kneeling, or stooping; walking more than a mile; walking several blocks; and walking one block. Two items that asked about moderate (such as bowling or vacuuming) and vigorous activities (such as running or lifting heavy objects) were not included as moderate and vigorous activity was one of our primary outcome variables. The scores ranged from 1 (*a lot*) to 4 (*not at all*) and were reverse-coded and averaged so that a higher score indicated worse functional health.

Perceived control. Perceived control was assessed with the MIDUS sense of control scale (Lachman & Weaver, 1998) at all three waves of data collection, however wave 3 was not included in our model as we were focused on perceived control as a predictor variable. This scale consisted of two subscales: personal mastery (e.g., I can do just about anything I really set my mind to) and perceived constraints (e.g., What happens in my life is often beyond my control). The scores ranged from 1 (*strongly agree*) to 7 (*strongly disagree*). Prenda and Lachman (2001) report high reliability for this scale ($\alpha = .85$). All items were coded so that a higher score reflected a greater sense of control. A latent variable of perceived control was constructed for Waves 1 and 2 from the observed scales of personal mastery and perceived constraints.

Physical activity. Physical activity was assessed through self-report at all three waves of data collection, however only Waves 2 and 3 are included in our model as we were focused on physical activity change as an outcome variable. At Waves 2 and 3, participants were asked to report how frequently they participated in vigorous (e.g., running or lifting heavy objects) and moderate physical activity (e.g., slow or light swimming, brisk walking) during both the summer months and the winter months, in home, work, and leisure settings (12 items total) using a scale ranging from 1 (*several times a week or more*) to 6 (*never*). Activity was assessed for winter and summer months to include both colder and warmer months, as people may differ in their activity levels across the seasons. All items in all waves were reverse coded so that a higher number indicates more physical activity.

Using the scoring method of Cotter and Lachman (2010), we created a continuous measure of physical activity. First the participant's highest moderate physical activity score from either the work, home, or leisure category in the summer months was averaged with the participant's highest moderate physical activity score from either the work, home, or leisure category in the winter months to create the participants' moderate activity score. In this manner, if the participant performed regular moderate activity in the home but not at work or during leisure time, the respondent was still classified as regularly moderately active. Identical procedures were followed to create vigorous physical activity scores. The highest score of these (moderate or vigorous) was used as the measure of frequency of physical activity, resulting in a physical activity score that could range from 1 to 6, with a higher number indicating greater levels of physical activity (the items are in Appendix). As suggested by Cotter and Lachman (2010), scoring this measure with this method yields the best approximation possible to data from the Centers for Disease Control and Prevention (Harris et al., 2013), which recommends that adults accumulate at least 150 min of moderate aerobic activity or 75 min of vigorous aerobic activity per week, or a mixture of both moderate and vigorous activity. Similar scoring procedures have been done before and yielded reliable results that were comparable to similar, well-established assessments from the CDC (Cotter & Lachman, 2010). Physical activity was included in the model as an observed construct.

Cognition. We assessed two cognitive factors, episodic memory (EM) and executive functioning (EF), at Waves 2 and 3 with the Brief Test of Adult Cognition by Telephone (BTACT). The BTACT is a battery composed of seven subtests that were designed to test six areas of cognition that are sensitive to age effects. The seven subtests make up two cognitive factors: EM and EF. A latent EM factor score was constructed with immediate and delayed word list recall scores, with a higher number reflecting better EM. A latent EF factor score was constructed with the observed scores for working memory span (backward digit span—the highest span achieved in repeating strings of digits in reverse order), verbal fluency (the number of words produced from the category of "animals" in 60 s), inductive reasoning (completing the pattern in a series of five numbers), processing speed (the number of digits produced by counting backward from 100 in 30 seconds), and attention switching and inhibitory control (the stop and go switch task; Lachman, Agrigoroaei, Tun, & Weaver, 2014). All tests were scored so that a higher number reflected better EF. See Lachman et al. (2014) for a more details on the BTACT and scoring. We estimated EM and EF as separate latent variables given previous work has demonstrated that EM and EF are differentially influenced by physical activity (Kramer et al., 1999).

Analyses

Using structural equation modeling (SEM), analyses involved two phases using the Mplus 7.4 software package (Muthén & Muthén, 1998–2007). The first phase involved the assessment of measurement model fit. The second phase tested our mediational hypotheses using a latent change score approach to examine both direct and indirect effects.

Model fit. SEM was utilized to analyze the covariance structure, estimate regression paths and error terms, and assess model fit. Missing data, which are extremely common in longitudinal studies, were also estimated with maximum likelihood (ML) procedures. Using ML methods in SEM has demonstrated to be accurate and less biased than conventional methods such as listwise or pairwise deletion (Enders & Bandalos, 2001). The following commonly used indices were used as benchmarks to assess the model fit: likelihood ratio chi-square, comparative fit index (CFI), and root mean squared error of approximation (RMSEA). Likelihood ratio chi-square provides a test for fit of the model based on the chi-squared distribution. The chi-square test is extremely sensitive to large sample sizes (Kline, 2005) and will always reject models with large sample sizes. Due to this issue, and the large sample sizes in the present study, chi-square values are reported but results for its associated significance test are not. For the CFI, values above .95 are generally considered a very good fit, and values above a .90 are considered a good fit (Bentler & Bonnett, 1980). It is commonly recommended that RMSEA values less than .06 indicate good fit, while values above .10 indicate poor fit (Hu & Bentler, 1998).

First, a measurement model was created to examine the model fit to the data. We began by specifying an initial measurement model for the time-varying latent constructs of perceived control, physical activity, EM, and EF. The loadings of personal mastery and immediate word list recall were fixed to 1.0 to scale the latent variables and identify the model. The loadings of the remaining variables were left free to be estimated. From this initial measurement model, we followed the recommended modification indices in a stepwise fashion to ensure the model was a good fit to the data. Next, a structural model was created with contemporaneous and cross-lagged paths from predictor to outcome variables. From this structural model, we formed a full model that examined the relationship between perceived control at Waves 1 and 2, physical activity Waves 2 and 3, EM at Waves 2 and 3, and EF at Waves 2 and 3, with Wave 1 age, sex, educational level, and functional health covarying at Wave 1 perceived control, and Wave 2 activity, EM, and EF. This model also included the latent change scores between waves for perceived control, physical activity, and EM and EF.

Mediation. Direct and indirect effects can be seen in Figure 1. The following four indirect effects were estimated:

1. Perceived $\text{Control}_1 \rightarrow \Delta$Physical Activity $\rightarrow \Delta$EM
2. ΔPerceived Control $\rightarrow \Delta$Physical Activity $\rightarrow \Delta$EM
3. Perceived $\text{Control}_1 \rightarrow \Delta$Physical Activity $\rightarrow \Delta$EF
4. ΔPerceived Control $\rightarrow \Delta$Physical Activity $\rightarrow \Delta$EF

Direct and indirect effects were reported using the MODEL INDIRECT option in Mplus. To further assess for evidence of mediation, asymmetric confidence intervals for the product of these paths were calculated (MacKinnon, 2008). If the confidence interval did not include zero, there was evidence of statistical mediation.

Reverse directionality. Past work regarding perceived control and its associated mechanisms and outcomes assumes the processes to be reciprocal and cyclical such that the outcomes (e.g., memory, physical declines, well-being) may impact one's control beliefs, self-efficacy, and feelings of mastery, or beliefs about one's abilities, and/or constraints, which in turn can impact possible behavioral or physiological mediators as well as future outcomes (Bandura, 1997; Soederberg-Miller & Lachman, 1999). Because of this, our mediation model was retested with EM and EF predicting perceived control at the next wave through physical activity. However, because MIDUS did not test for cognition at Wave 1, this reverse mediation model only included Waves 2 and 3.

Family dependence. As the MIDUS sample included siblings of the main respondents and a subpopulation of twins, in line with past work (Hughes, Agrigoroaei, Jeon, Bruzzese, & Lachman, 2011; Lachman & Agrigoroaei, 2010), all analyses were reexamined within a multilevel structure in Mplus that clustered data based on family ID. This predicted robust, sandwich estimates of standard error by clustering at the family level to account for potential nonindependence in the data set. Parameter estimates obtained from these analyses accounting for this data clustering were analogous with our original models. There were a few differences in *p* values of our predicted direct effects, however there were no differences in our predicted indirect effects. Because the models were similar, the following reports results from our original analyses that excluded the family random effects term from the model.

Results

Using structural equation modeling (SEM), analyses involved two phases using the Mplus 7.4 software package (Muthén & Muthén, 1998–2007). We first constructed a measurement model for the time-varying latent constructs of perceived control and cognition. The loadings for each latent construct were set to be equal across occasions, given the assumption of structural invariance in terms of factor loadings, as this was the best fit found in Hughes et al. (2011). The model indicated a poor fit to the data, $\chi^2(165) = 4326.87$, $p < .05$, comparative fit index (CFI) = .828, and root mean square error of approximation (RMSEA) = .062. As expected with models using the same measures across multiple time points (Cole & Maxwell, 2003), modification indices suggested that allowing the residual terms of observed variables to correlate across waves would significantly improve model fit. Residual terms were freed in a stepwise fashion, starting with the measure that would provide the greatest improvement to model fit according to the modification indices. Following these modifications, the model provided a good fit to the data, $\chi^2(129) = 1628.10$, $p < .05$, CFI = .936, RMSEA = .042.

On the basis of our measurement model, we used a latent change model in which we constructed latent variables to represent change between waves of perceived control, physical activity, and cognition. We also controlled for age, sex, education, and health at

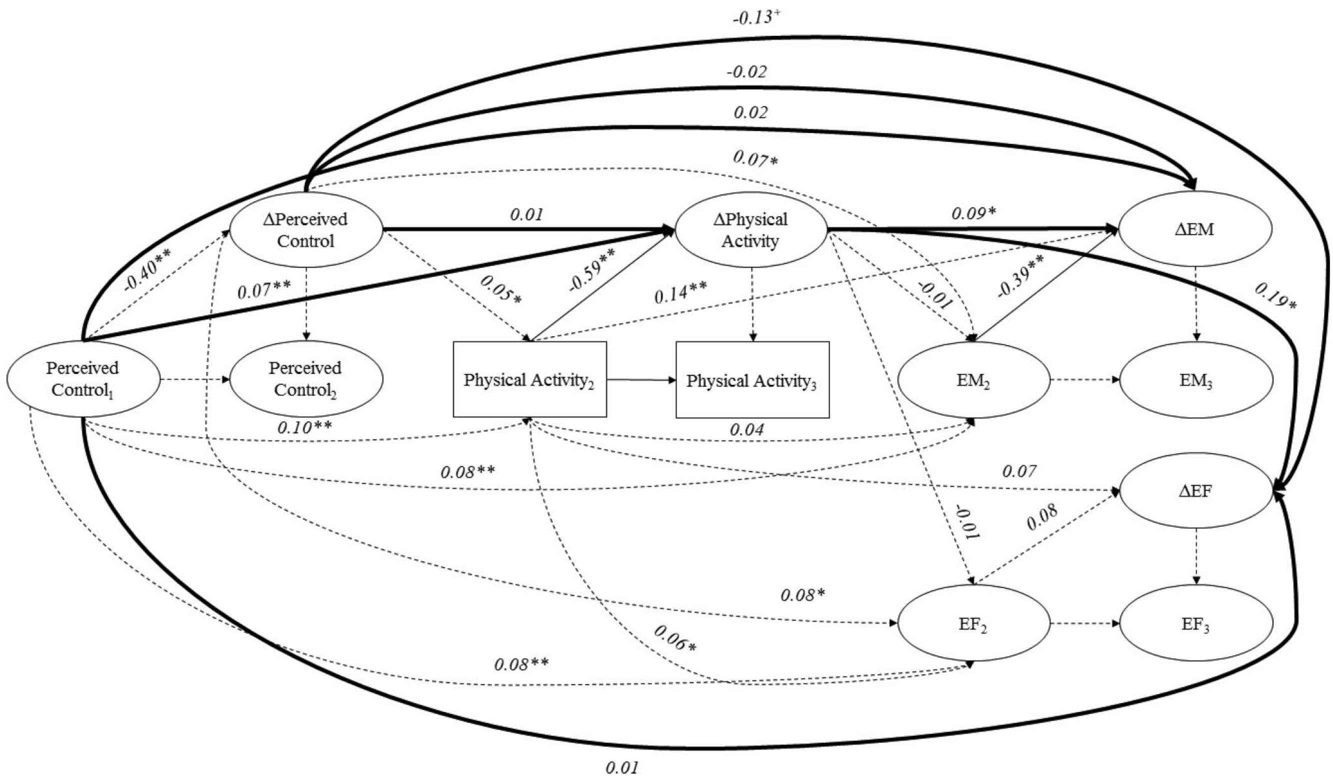

Figure 1. Latent difference score diagram with standardized estimates. Numbered subscripts indicate wave number (1 = Wave 1, 2 = Wave 2, 3 = Wave 3); Δ = change; PC = perceived control; PA = physical activity; EM = episodic memory; EF = executive functioning; all paths shown were estimated as direct paths. Dotted paths indicate paths not included in estimated indirect effects and solid paths indicate paths in estimated indirect effects. Covariates age, gender, education, and functional health not shown in model for visual clarity. $^{+}$ $p < .06$. * $p < .05$. ** $p < .001$.

Wave 1 perceived control, and Wave 2 physical activity and cognition. This model provided a good fit to the data, $\chi^2(211) = 2162.66$, $p < .05$, CFI = .929, RMSEA = .038 (Table 3). Results from the latent change score analyses to assess longitudinal mediation can be found in Table 4 which lists the results of the standardized estimates for all possible pathways, including direct and indirect effects, and the associated 95% bias-corrected bootstrap confidence. A diagram of this model can be found in Figure 1.

Table 3
Standardized Estimates of Factor Loadings

Factor	Wave 1			Wave 2			Wave 3		
	Estimate	*SE*	*p*	Estimate	*SE*	*p*	Estimate	*SE*	*p*
Perceived control									
Mastery	1.00	—	—	1.00	—	—			
Constraints	2.73	.06	<.001	2.73	.06	<.001			
EM									
Word list immediate				1.00	—	—	1.00	—	—
Word list delay				1.10	.02	<.001	1.10	.02	<.001
EF									
Digits backwards				1.00	—	—	1.00	—	—
Category fluency				5.85	.25	<.001	5.85	.25	<.001
Backwards counting				14.46	.56	<.001	14.46	.56	<.001
Number series				1.48	.06	<.001	1.48	.06	<.001
Stop–Go switch				.21	.01	<.001	.21	.01	<.001

Note. *SE* = Standard Error; EM = Episodic Memory; EF = Executive Functioning; Model Fit: $\chi^2(211) = 2162.66$, $p < .05$, comparative fit index = .929, root mean square error of approximation = .038. The first parameter of each latent variable were fixed and therefore the standard errors and p values are not defined.

Table 4
Unstandardized Estimates and Significance Levels for Latent Difference Score Mediation Model

Effects	Estimate	*SE*	*p*	95% Lower	95% Upper
Covariates					
Age_1 → Perceived Control1	−.00	.00	.04	−.00	.00
Age_1 → $Activity_2$	−.11	.03	<.001	−.02	−.02
Age_1 → EM_2	−.05	.00	<.001	−.06	−.05
Age_1 → EF_2	−.02	.00	<.001	−.03	−.02
Sex_1 → Perceived $Control_1$	−.03	.01	.014	−.05	−.01
Sex_1 → $Activity_2$	−.1	.03	.002	−.17	−.04
Sex_1 → EM_2	1.14	.06	<.001	1.02	1.26
Sex_1 → EF_2	−.11	.02	<.001	−.14	−.07
$Education_1$ → Perceived $Control_1$	.03	.00	<.001	.02	.03
$Education_1$ → $Activity_2$	.05	.01	<.001	.04	.07
$Education_1$ → EM_2	.16	.01	<.001	.14	.19
$Education_1$ → EF_2	.08	.01	<.001	.08	.09
$Health_1$ → Perceived $Control_1$	.16	.01	<.001	.15	.18
$Health_1$ → $Activity_2$	.11	.03	<.001	.05	.17
$Health_1$ → EM_2	.24	.06	<.001	.13	.35
$Health_1$ → EF_2	.09	.02	<.001	.06	.12
Direct Effects					
Perceived $Control_1$ → ΔPerceived Control	−.27	.02	<.001	−.31	−.24
Perceived $Control_1$ → $Activity_2$	.22	.04	<.001	.14	.30
ΔPerceived Control → $Activity_2$	.17	.08	<.001	.02	.32
Perceived $Control_1$ → ΔActivity	.18	.05	<.001	.09	.28
ΔPerceived Control → ΔActivity	.03	.09	.783	−.16	.21
$Activity_2$ → ΔActivity	−.65	.02	<.001	−.69	−.62
Perceived $Control_1$ → EM_2	.36	.08	<.001	.21	.51
ΔPerceived Control → EM_2	.45	.16	.005	.14	.76
Activity2 → EM_2	.07	.05	.010	−.02	.16
ΔActivity → EM_2	−.02	.04	.614	−.11	.07
Perceived $Control_1$ → ΔEM	.09	.1	.356	−.10	.27
ΔPerceived Control → ΔEM	−.12	.2	.538	−.51	.27
$Activity_2$ → ΔEM	.24	.05	<.001	.14	.33
ΔActivity → ΔEM	.14	.04	.001	.01	.05
EM_2 → ΔEM	−.34	.02	<.001	−.38	−.30
Perceived Control1 → EF_2	.11	.02	<.001	.06	.15
ΔPerceived Control → EF_2	.16	.05	.001	.06	.25
$Activity_2$ → EF_2	.03	.01	.009	.01	.06
ΔActivity → EF_2	−.01	.01	.679	−.03	.02
Perceived Control1 → ΔEF	.00	.02	.847	−.03	.04
ΔPerceived Control → ΔEF	−.08	.04	.056	−.16	.00
$Activity_2$ → ΔEF	.01	.01	.262	−.01	.03
ΔActivity → ΔEF	.03	.01	.001	.01	.05
EF_2 → ΔEF	.02	.02	.174	−.01	.06
Covariances					
$Mastery_1$ ↔ $Mastery_2$	.36	.01	<.001	.33	.39
$Constraints_1$ ↔ $Constraints_2$	−.29	.02	<.001	−.34	−.24
Word List $Imm._2$ ↔ Word List $Imm._3$	−.07	.08	.344	−.21	.07
Word List $Del._2$ ↔ Word List $Del._3$	.49	.09	<.001	.31	.67
Digits $Backwards_2$ ↔ Digits $Backwards_3$	.69	.04	<.001	.61	.77
Category $Fluency_2$ ↔ Category $Fluency_3$	12.48	.59	<.001	11.32	13.64
Back. $Counting_2$ ↔ Back. $Counting_3$	36.78	1.84	<.001	33.17	40.39
Number $Series_2$ ↔ Number $Series_3$	.59	.05	<.001	.49	.68
Stop–Go $Switch_2$ ↔ Stop–Go $Switch_3$	.02	1.84	<.001	.01	.02
Indirect Effects					
Perceived $Control_1$ → ΔPhysical Activity → ΔEM				.006	.047
ΔPerceived Control → ΔPhysical Activity → ΔEM				−.023	.03
Perceived $Control_1$ → ΔPhysical Activit y→ ΔEF				.001	.01
ΔPerceived Control → ΔPhysical Activity → ΔEF				−.005	.006

Note. Numbered subscripts indicate wave number (1 = Wave 1, 2 = Wave 2, 3 = Wave 3); Δ = change*;* EM = episodic memory; EF = executive functioning; Model fit: $\chi^2(211) = 2162.66$, $p < .05$, comparative fit index = .929, root mean square error of approximation = .038; Loadings for perceived control at Wave 1 and Wave 2 were constrained to be equal, activity at Wave 2 and 3 and loadings for cognition at Wave 2 and 3 were constrained to be equal.

Covariates

Greater education ($p < .001$) and health ($p < .001$), and being male ($p = .014$) all significantly predicted a greater perceived control at Wave 1. Age was not significantly related to perceived control ($p = .040$, 95% CI [−0.00, –0.00]). Younger age, higher education, and better functional health significantly predicted higher engagement in physical activity at Wave 2 ($p < .001$ for all effects). Males were more likely to report engaging in more physical activity ($p = .002$). Younger age ($p < .001$), higher education ($p < .001$), better health ($p < .001$), and females ($p < .001$) demonstrated significantly better EM at Wave 2. Younger age ($p < .001$), more education ($p < .001$), better functional health ($p < .001$), and females ($p < .001$) significantly demonstrated better EF at Wave 2.

Direct Effects

Perceived control. As is often the case with psychological measures that do not have perfect reliability, initial level of perceived control was negatively related to change in perceived control ($\beta = -0.40$, $SE = 0.02$, $p < .001$), which may reflect regression toward the mean. We elaborate on this further in the discussion section.

Physical activity. Both level of perceived control at Wave 1 ($\beta = 0.10$, $SE = 0.02$, $p < .001$) and change in perceived control from Wave 1 to 2 ($\beta = 0.05$, $SE = 0.02$, $p = .027$) predicted greater activity at Wave 2. Interestingly, activity level at Wave 2 negatively predicted change in activity to Wave 3 ($\beta = -0.59$, $SE = .01$, $p < .001$). Change in perceived control from Wave 1 to 2 did not predict change in activity from Wave 2 to 3; however, level of perceived control at Wave 1 did predict less change in activity from Wave 2 to 3 ($\beta = 0.07$, $SE = 0.02$, $p < .001$).

Cognition.

Episodic memory. Being more active at Wave 2 was not significantly associated with better EM at Wave 2. Additionally, greater levels of perceived control at Wave 1 ($\beta = 0.08$, $SE = 0.02$, $p < .001$) and greater change in perceived control from Wave 1 to Wave 2 ($\beta = 0.07$, $SE = 0.02$, $p = .004$) predicted better EM at Wave 2. Change in activity level was not associated with EM at Wave 2.

Neither level of perceived control at Wave 1, nor change in perceived control from Wave 1 to 2, predicted change in EM. Activity level at Wave 2 did significantly predict less decline in EM from Wave 2 to Wave 3 ($\beta = 0.14$, $SE = 0.03$, $p < .001$). Change in activity from Wave 2 to 3 was significantly associated with less decline in EM ($\beta = 0.09$, $SE = 0.03$, $p = .001$). EM at Wave 2 negatively predicted decline in EM at Wave 3 ($\beta = -0.39$, $SE = 0.02$, $p < .001$).

Executive functioning. Being more active at wave 2 was significantly associated with better EF at Wave 2 ($\beta = 0.06$, $SE = 0.02$, $p = .009$). Additionally, greater levels of perceived control at Wave 1 ($\beta = 0.08$, $SE = 0.02$, $p < .001$) and greater change in perceived control from Wave 1 to Wave 2 ($\beta = 0.08$, $SE = 0.02$, $p = .001$) predicted better EF at Wave 2. Change in activity level was not associated with EF at Wave 2.

Level of perceived control at wave 1 did not predict decline in EF, nor did change in perceived control from Wave 1 to 2 to change in EF ($p = .054$, 95% CI [−0.155, 0.002]). Activity level at Wave 2 did not significantly predict decline in EF from Wave 2 to Wave 3. An increase in activity from Wave 2 to 3 ($\beta = 0.18$, $SE = 0.05$, $p = .001$) was significantly associated with less decline in EF. Level of EF at Wave 2 did not significantly predict less decline in EF.

Indirect Effects

We estimated two indirect effects in the latent change score model for both episodic memory and executive functioning, resulting in four total indirect effects. Table 4 shows these four indirect effects, and the associated 95% bias-corrected bootstrap confidence intervals. Figure 1 shows the standardized estimate labels for all paths in the latent change score model. There is evidence supporting the presence of two of these indirect effects.

Episodic memory. Our first predicted indirect effect was supported, such that change in physical activity mediated the relationship between initial level of perceived control and less decline in EM (95% CI [.002, .012]). Our second predicted indirect effect of change in perceived control and change in EM mediated by change in physical activity was not supported. Overall, our results support that a higher initial level of perceived control predicted less decline in EM, and this was mediated by an increase in physical activity.

Executive functioning. Our first predicted indirect effect was supported, in that change in physical activity mediated the relationship between initial level of perceived control and change in EF (95% CI [.002, .012]). Our second predicted indirect effect of change in perceived control and change in EF mediated by change in physical activity was not supported. Overall, our results support that a higher initial level of perceived control predicted less decline in EM, and this was mediated by an increase in physical activity.

Reverse Directionality

To see if EM or EF predicted later perceived control, and if this relationship was mediated by physical activity, we constructed a reversed model. This reversed model fit the data well, $\chi^2(218) = 2195.21$, $p < .05$, CFI = .924, RMSEA = .046. For direct effects, neither initial level of EM nor EF at Wave 2 predicted less decline in perceived control from Wave 2 to Wave 3. However, there was a significant relationship between activity and change in perceived control from Wave 2 to 3 ($\beta = 0.06$, $SE = 0.03$, $p = .043$). There were no significant indirect effects from initial level of EM or EF at Wave 2 to change in perceived control from Wave 2 to 3 through change in physical activity. Thus, the results are more consistent with the predicted direction of effects.

Discussion

In general, results support the prediction that physical activity mediated the longitudinal relationship between perceived control and cognitive functioning 20 years later. This study provides support for the conceptual models of health behaviors, such as physical activity, as mediators of the relationship between perceived control and age-related outcomes, such as cognitive functioning (Robinson & Lachman, 2016; Soederberg-Miller & Lachman, 1999). Infurna and Gerstorf's (2013) previous empirical work found that level of, and 2 year change in, physical activity mediated the relationship between perceived control and episodic memory (EM). The present study extended these findings not only to another cognitive domain, executive functioning (EF), but across a longer time frame (10 to 20 years compared with 4 years) as well as a focus earlier in midlife, when perceived control is perhaps at the most risk for decline (e.g., Lachman, 2006; Lachman et al., 2011; Mirowsky & Ross, 2007).

Although the initial descriptive analyses and correlations indicated that EM and executive functioning EF were similarly related to perceived control and physical activity, previous work suggesting selective effects of physical activity on EM versus EF (e.g., Colcombe & Kramer, 2003; Kramer et al., 1999) prompted us to examine these direct and indirect effects as two separate factors. The pattern of direct effects between EM and EF were similar. In line with our predictions and previous work (e.g., Infurna & Gerstorf, 2013; Lachman, 2006; Lachman et al., 2011; Salthouse, 2009), physical activity, EM, and EF were all negatively related to age. Controlling for age, gender, education, and functional health, our results demonstrated that initial level of perceived control at wave 1 predicted level of physical activity 10 years later, and change in physical activity 10 years after that. However, change in perceived control did not predict change in activity. Those who reported being more physically active demonstrated better EM and EF, but not change in EM or EF. However, if one increased their activity level they were less likely to decline in EM and EF.

We see evidence that initial level of perceived control predicted less decline in both EM and EF 20 years later, mediated by change in physical activity. Level refers to individual differences in the amount of control, whereas change refers to the within-person differences from one wave to the next. One of the problems when assessing change in psychological research has been regression toward the mean (Nesselroade, Stigler, & Baltes, 1980; Raykov, 1993). Salthouse (2012) discusses the effects of regression toward the mean in longitudinal models examining cognitive change. He suggests that the effects of regression toward the mean could be operating in many latent change analyses in which relations of the intercept and slope are examined. That is, negative relationships could reflect more positive change at lower ability levels, and positive relationships could be underestimates of the true effects because they may be attenuated by regression effects (Salthouse, 2012). Indeed, in our model we do see that initial level of perceived control, physical activity, EM, and EF are all negatively related to their respective change scores. It is possible that those who were lower in our outcomes of interest may have had more room to improve on the subsequent wave of testing; however, on average, perceived control, EM, and EF declined across waves. Because the relationships between perceived control, physical activity, and cognition are thought to vary with age, we first tested the latent change score model when controlling for age, and then examined the model separately, for three age groups: young (<1 standard deviation below the mean), middle-aged (one standard deviation below to one standard deviation above the mean), and older adults (>1 standard deviation above the mean). The pattern of results for these models was consistent across age groups. This suggests that change in physical activity mediates the relationship between initial level of perceived control and change in cognition for young, middle-aged, and older adults, which is consistent with previous work (Infurna & Gerstorf, 2013). Perhaps this is not surprising, as perceived control was not significantly related to age.

The MIDUS dataset offers an impressive depth of longitudinal data with three waves spanning 20 years. However, in our model, with three waves of control beliefs data and only two waves of cognitive data, we are unable to include change scores with completely distinct time frames (i.e., we included perceived control from Wave 1 to Wave 2, physical activity from Wave 2 to Wave 3, and cognition from Wave 2 to Wave 3). As such, our change score for physical activity does not temporally precede the period of change in cognitive performance, rather the model considers simultaneous change in cognition. However, we have some preliminary support for the direction of effects, as we did not find support for mediation in our reversed model (where EM and EF are predictor variables and perceived control is the outcome). Therefore, we have some added confidence for the interpretation of the parameter estimates and the direction of effects. It is promising, in terms of the directionality of the predicted model, that the reversed model did not provide evidence for significant indirect effects from initial level of cognition to change in perceived control through change in physical activity. Although this comparison can offer support for the predicted direction of these relationships, it is important to note that reversing the arrows in a mediation model and comparing them is not the final step in determining directionality (Thoemmes, 2015). More definitive conclusions will depend on the collection of additional waves of measurement to investigate directionality within these relationships to test reciprocal models of change (Robinson & Lachman, 2016; Soederberg-Miller & Lachman, 1999).

Limitations and Future Directions

This study was the first attempt, to our knowledge, to examine the mediational role of physical activity in the relationship between perceived control and cognition across a span of two decades. However, several limitations should be noted as future avenues to continue and expand on this work. One limitation is a lack of objective physical activity measurement. Although self-report measurements are useful to help gain insight into one's level of physical activity, they possess several limitations in terms of their reliability and validity, such as a capacity to over- or underestimate true physical activity and/or inactivity, and potential issues of recall and response bias (e.g., social desirability, inaccurate memory) (Prince et al., 2008; Shephard, 2003). Future work could objectively measure physical activity with direct measures such as calorimetry, physiologic markers, and motion sensors and monitors, such as accelerometers, pedometers, and heart rate monitors (Sullivan & Lachman, 2017). Objective assessments, and more trials or items at each wave of assessment, could help to reduce measurement error and the magnitude of any regression toward the mean artifacts (Barnett, van der Pols, & Dobson, 2005). The use of structural equation models with latent factors and latent change scores is one way to address issues of unreliability of measurement and potential regression to the mean (McArdle & Nesselroade, 2014).

Additionally, although both EM and EF did, on average, decline from Wave 2 to Wave 3, there may be possible retest effects from the repeated assessment of cognition. However, previous work suggests that after an interval of 7 years, retest effects are typically not detectable (Salthouse, Schroeder, & Ferrer, 2004). As the average interval between waves in MIDUS was 9 years, the potential retest gains are expected to be minimal. Indeed, recent work compared the longitudinal sample to another similar sample that had only taken the BTACT once and found no significant retest effects (Hughes et al., 2011). Another potential limitation lies in the auditory nature of the cognitive test. Although methods were taken in attempt to eliminate any confounding age effects due to hearing loss by administering a brief hearing test prior to the BTACT, it is possible that age-related differences in cognition may be due to age-related differences in hearing. Only a small number of adults reported hearing problems and in those cases the volume was adjusted. Moreover, a previous study found age-related differences in the BTACT were unchanged after controlling for self-rated hearing (Lachman et al., 2014). Nevertheless, more sensitive audiometric assessments would be helpful for a more comprehensive understanding of the impact of hearing on the BTACT performance (Wingfield, Tun, & McCoy, 2005).

Examining if physical activity acts as a mediator between perceived control and cognition is, in reality, only the tip of a complex iceberg that elicits further inquiries as to the mechanisms involved within these specific relationships. That is, why does a greater perception of control lead to more physical activity? Perhaps perceived control over one's daily life and schedule is what is driving this relationship. Future work should aim to investigate this mechanism. Of note, we did examine our latent change mediation model separately for moderate activity and for vigorous physical activity and found a similar pattern of significant results for the two intensities. These results were comparable to the model that included both intensities together. Current work is beginning to examine the dose response of physical activity on cognition; that is, how much is necessary to make a difference (e.g., U.S. National Library of Medicine, 2016; Vidoni et al., 2015). The relationships between perceived control, physical activity, and cognition are well-documented, and the current study empirically supports physical activity as a mechanism between control and cognition; however, more work is needed to understand to what degree one needs to increase their sense of control or activity to see substantial differences (Erickson et al., 2015).

Physical activity is just one example of engagement in a healthy habit that is associated with enhanced cognition later in life. Although there is specific neuronal evidence as to why physical activity is beneficial for cognition, it may also be beneficial in that engaging in physical activity is associated with engaging in other healthy habits, such as maintaining a particular diet or engaging in cognitively stimulating activities, which would also predict enhanced cognition (Otaegui-Arrazola, Amiano, Elbusto, Urdaneta, & Martínez-Lage, 2014). Engagement in other healthy habits would likely require a higher sense of control, as well. Forthcoming work would benefit from examining other mechanisms linking perceived control and cognition, such as engagement in other healthy habits (cognitive activity, social contact, diet, etc.). Finally, the cognitive benefits of physical activity are well-known, yet a recent report suggests that only about 20% of adults meet the recommended guidelines for physical activity (Clarke, Norris, & Schiller, 2017). Future studies are needed to further investigate the importance of perceived control for engaging in regular physical activity throughout life as a means to maintaining cognitive health (Lachman, Lipsitz, Lubben, Castaneda-Sceppa, & Jette, 2018; Robinson & Lachman, 2016). This is particularly important as the transition from midlife to older adulthood typically coincides with the transition from working to retirement, where regular activity from a steadier schedule can be disrupted and there is a need to find strategies to maintain consistent activity.

Conclusion

Overall, this study provides support for theoretically derived predictions about health behaviors, such as physical activity, as mediators of the relationship between perceived control and age-related outcomes, such as cognitive functioning (Robinson & Lachman, 2016; Soederberg-Miller & Lachman, 1999). Additionally, this study expands on previous empirical work by demonstrating that physical activity not only plays a mediational role between perceived control and episodic memory, but that it is also an important mechanism related to executive functioning. Additionally, our results demonstrate a long-term longitudinal relationship between perceived control and cognitive functioning over 20 years later, from midlife to older adulthood, when perceived control is typically most vulnerable to decline (e.g., Lachman, 2006; Lachman et al., 2011; Mirowsky & Ross, 2007). Those who had higher perceived control and increased their physical activity were less likely to show declines in episodic memory and executive functioning 20 years later. This study highlights the importance of maintaining one's sense of control into older adulthood and can inform future policy work and intervention development aimed at enhancing physical and cognitive health in an aging population.

References

Agrigoroaei, S., & Lachman, M. E. (2011). Cognitive functioning in midlife and old age: Combined effects of psychosocial and behavioral factors. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 66*(Suppl. 1), i130–i140. http://dx.doi.org/10.1093/geronb/gbr017

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York, NY: Freeman.

Barnett, A. G., van der Pols, J. C., & Dobson, A. J. (2005). Regression to the mean: What it is and how to deal with it. *International Journal of Epidemiology, 34,* 215–220. http://dx.doi.org/10.1093/ije/dyh299

Bentler, P. M., & Bonnett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin, 88,* 588–606. http://dx.doi.org/10.1037/0033-2909.88.3.588

Brim, O., Ryff, C., & Kessler, R. (2004). The MIDUS national survey: An overview. In O. Brim, C. Ryff, & R. Kessler, *How healthy are we? A national study of well-being* (pp. 1–34). Chicago, IL: The University of Chicago Press.

Caplan, L. J., & Schooler, C. (2003). The roles of fatalism, self-confidence, and intellectual resources in the disablement process in older adults. *Psychology and Aging, 18,* 551–561. http://dx.doi.org/10.1037/0882-7974.18.3.551

Centers for Disease Control and Prevention (CDC). (2013). Adult participation in aerobic and muscle-strengthening physical activities—United States, 2011. *Morbidity and Mortality Weekly Report, 62,* 326–330.

Clarke, T. C., Norris, T., & Schiller, J. S. (2017). *Early release of selected estimates based on data from the 2016 National Health Interview Survey*. Retrieved from https://www.cdc.gov/nchs/data/nhis/earlyrelease/earlyrelease201705.pdf

Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychological Science, 14,* 125–130. http://dx.doi.org/10.1111/1467-9280.t01-1-01430

Colcombe, S. J., Kramer, A. F., Erickson, K. I., Scalf, P., McAuley, E., Cohen, N. J., . . . Elavsky, S. (2004). Cardiovascular fitness, cortical plasticity, and aging. *Proceedings of the National Academy of Sciences of the United States of America, 101,* 3316–3321. http://dx.doi.org/10.1073/pnas.0400266101

Cole, D. A., & Maxwell, S. E. (2003). Testing mediational models with longitudinal data: Questions and tips in the use of structural equation modeling. *Journal of Abnormal Psychology, 112,* 558–577. http://dx.doi.org/10.1037/0021-843X.112.4.558

Cotter, K. A., & Lachman, M. E. (2010). No strain, no gain: psychosocial predictors of physical activity across the adult lifespan. *Journal of Physical Activity and Health, 7,* 584–594.

Enders, C. K., & Bandalos, D. L. (2001). The relative performance of full information maximum likelihood estimation for missing data in structural equation models equation models. *Structural Equation Modeling, 8,* 430–457. http://dx.doi.org/10.1207/S15328007SEM0803_5

Erickson, K. I., Hillman, C. H., & Kramer, A. F. (2015). Physical activity, brain, and cognition. *Current Opinion in Behavioral Sciences, 4,* 27–32. http://dx.doi.org/10.1016/j.cobeha.2015.01.005

Erickson, K. I., Voss, M. W., Prakash, R. S., Basak, C., Szabo, A., Chaddock, L., . . . Wojcicki, T. R. (2011). Exercise training increases size of hippocampus and improves memory. *Proceedings of the National Academy of Sciences, 108,* 3017–3022.

Frederiksen, K. S., Verdelho, A., Madureira, S., Bäzner, H., O'Brien, J. T., Fazekas, F., . . . the LADIS Study. (2015). Physical activity in the elderly is associated with improved executive function and processing speed: The LADIS Study. *International Journal of Geriatric Psychiatry, 30,* 744–750. http://dx.doi.org/10.1002/gps.4220

Harris, C., Watson, K., Carlson, S., Fulton, J., Dorn, J., & Elam-Evans, L., & the Centers for Disease Control and Prevention. (2013). Adult participation in aerobic and muscle-strengthening physical activities—United States, 2011. *Morbidity and Mortality Weekly Report, 62,* 326–330.

Hooker, K., & McAdams, D. P. (2003). Personality reconsidered: A new agenda for aging research. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 58,* 296–304. http://dx.doi.org/10.1093/geronb/58.6.P296

Hu, L. T., & Bentler, P. M. (1998). Fit indices in covariance structure modeling: Sensitivity to underparameterized model misspecification. *Psychological Methods, 3,* 424–453. http://dx.doi.org/10.1037/1082-989X.3.4.424

Hughes, M. L., Agrigoroaei, S., Jeon, M., Bruzzese, M., & Lachman, M. E. (2011). *Change in cognitive performance from midlife into old age: Findings from the Midlife in the United States (MIDUS) study*. Waltham, MA: Brandeis University.

Infurna, F. J., & Gerstorf, D. (2013). Linking perceived control, physical activity, and biological health to memory change. *Psychology and Aging, 28,* 1147–1163. http://dx.doi.org/10.1037/a0033327

Infurna, F. J., & Gerstorf, D. (2014). Perceived control relates to better functional health and lower cardio-metabolic risk: The mediating role of physical activity. *Health Psychology, 33,* 85–94. http://dx.doi.org/10.1037/a0030208

Infurna, F. J., & Okun, M. A. (2015). Antecedents and outcomes of level and rates of change in perceived control: The moderating role of age. *Developmental Psychology, 51,* 1420–1437. http://dx.doi.org/10.1037/a0039530

Infurna, F. J., Ram, N., & Gerstorf, D. (2013). Level and change in perceived control predict 19-year mortality: Findings from the Americans' changing lives study. *Developmental Psychology, 49,* 1833–1847. http://dx.doi.org/10.1037/a0031041

Kline, R. B. (2005). *Principles and Practice of Structural Equation Modeling* (2nd ed.). New York, NY: The Guilford Press.

Kramer, A. F., Hahn, S., Cohen, N. J., Banich, M. T., McAuley, E., Harrison, C. R., . . . Colcombe, A. (1999). Ageing, fitness and neurocognitive function. *Nature, 400,* 418–419. http://dx.doi.org/10.1038/22682

Lachman, M. E. (2006). Perceived Control Over Aging-Related Declines. *Current Directions in Psychological Science, 15,* 282–286. http://dx.doi.org/10.1111/j.1467-8721.2006.00453.x

Lachman, M. E., & Agrigoroaei, S. (2010). Promoting functional health in midlife and old age: Long-term protective effects of control beliefs, social support, and physical exercise. *PLoS ONE, 5,* e13297. http://dx.doi.org/10.1371/journal.pone.0013297

Lachman, M. E., & Agrigoroaei, S. (2012). Low perceived control as a risk factor for episodic memory: The mediational role of anxiety and task interference. *Memory & Cognition, 40,* 287–296. http://dx.doi.org/10.3758/s13421-011-0140-x

Lachman, M. E., Agrigoroaei, S., & Rickenbach, E. H. (2015). Making sense of control: Change and consequences. In R. A. Scott & S. M. Kosslyn (Eds.), *Emerging trends in the social and behavioral sciences* (pp. 1–16). Hoboken, NJ: Wiley. http://dx.doi.org/10.1002/9781118900772.etrds0209

Lachman, M. E., Agrigoroaei, S., Tun, P. A., & Weaver, S. L. (2014). Monitoring cognitive functioning: Psychometric properties of the brief test of adult cognition by telephone. *Assessment, 21,* 404–417. http://dx.doi.org/10.1177/1073191113508807

Lachman, M. E., & Andreoletti, C. (2006). Strategy use mediates the relationship between control beliefs and memory performance for middle-aged and older adults. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 61,* 88–94. http://dx.doi.org/10.1093/geronb/61.2.P88

Lachman, M., & Firth, K. (2004). The adaptive value of feeling in control during midlife. In O. Brim, C. Ryff, & R. Kessler (Eds.), *How healthy are we? A national study of well-being at midlife* (pp. 320–349). Chicago, IL: The University of Chicago Press.

Lachman, M. E., Lipsitz, L., Lubben, J., Castaneda-Sceppa, C., & Jette, A. (2018). When adults don't exercise: Behavioral strategies to increase physical activity in sedentary middle-aged and older adults. *Innovation in Aging*. Advance online publication. http://dx.doi.org/10.1093/geroni/igy007

Lachman, M. E., Neupert, S. D., & Agrigoroaei, S. (2011). The relevance of control beliefs for health and aging. In K. W. Schaie & S. L. Willis (Eds.), *Handbook of the psychology of aging* (7th ed.; pp. 175–190). New York, NY: Elsevier. http://dx.doi.org/10.1016/B978-0-12-380882-0.00011-5

Lachman, M. E., & Weaver, S. L. (1998). Sociodemographic variations in the sense of control by domain: Findings from the MacArthur studies of midlife. *Psychology and Aging, 13,* 553–562. http://dx.doi.org/10.1037/0882-7974.13.4.553

Lachman, M. E., Weaver, S. L., Bandura, M., Elliott, E., & Lewkowicz, C. J. (1992). Improving memory and control beliefs through cognitive restructuring and self-generated strategies. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 47,* 293–299. http://dx.doi.org/10.1093/geronj/47.5.P293

MacKinnon, D. (2008). *An introduction to statistical mediation analysis*. Mahwah, NJ: Lawrence Erlbaum.

McArdle, J., & Nesselroade, J. R. (2014). *Longitudinal data analysis using structural equation models*. Washington, DC: American Psychological Association. http://dx.doi.org/10.1037/14440-000

Mirowsky, J., & Ross, C. E. (2007). Life course trajectories of perceived control and their relationship to education. *American Journal of Sociology, 112,* 1339–1382. http://dx.doi.org/10.1086/511800

Muthén, L., & Muthén, B. (1998–2007). *Mplus user's guide* (4th ed.). Los Angeles, CA: Author.

Nesselroade, J. R., Stigler, S. M., & Baltes, P. B. (1980). Regression toward the mean and the study of change. *Psychological Bulletin, 88,* 622–637. http://dx.doi.org/10.1037/0033-2909.88.3.622

Otaegui-Arrazola, A., Amiano, P., Elbusto, A., Urdaneta, E., & Martínez-Lage, P. (2014). Diet, cognition, and Alzheimer's disease: Food for thought. *European Journal of Nutrition, 53,* 1–23. http://dx.doi.org/10.1007/s00394-013-0561-3

Prenda, K. M., & Lachman, M. E. (2001). Planning for the future: A life management strategy for increasing control and life satisfaction in adulthood. *Psychology and Aging, 16,* 206–216. http://dx.doi.org/10.1037/0882-7974.16.2.206

Prince, S. A., Adamo, K. B., Hamel, M. E., Hardt, J., Connor Gorber, S., & Tremblay, M. (2008). A comparison of direct versus self-report measures for assessing physical activity in adults: A systematic review. *The International Journal of Behavioral Nutrition and Physical Activity, 5,* 56. http://dx.doi.org/10.1186/1479-5868-5-56

Raykov, T. (1993). A structural equation model for measuring residualized change and discerning patterns of growth or decline. *Applied Psychological Measurement, 17,* 53–71. http://dx.doi.org/10.1177/014662169301700110

Rebok, G., Rasmusson, D. X., & Brandt, J. (1996). Prospects for computerized memory training in normal elderly: Effects of practice on explicit and implicit memory tasks. *Applied Cognitive Psychology, 10,* 211–223. http://dx.doi.org/10.1002/(SICI)1099-0720(199606)10:3<211::AID-ACP375>3.0.CO;2-C

Robinson, S. A., & Lachman, M. E. (2016). Perceived control and behavior change: A personalized approach. In J. W. Reich & F. J. Infurna (Eds.), *Perceived control: Theory, research, and practice in the first 50 years* (pp. 201–227). New York, NY: Oxford University Press.

Rodin, J. (1986). Aging and health: Effects of the sense of control. *Science, 233,* 1271–1276. http://dx.doi.org/10.1126/science.3749877

Roepke, S. K., & Grant, I. (2011). Toward a more complete understanding of the effects of personal mastery on cardiometabolic health. *Health Psychology, 30,* 615–632. http://dx.doi.org/10.1037/a0023480

Salthouse, T. A. (2009). When does age-related cognitive decline begin? *Neurobiology of Aging, 30,* 507–514. http://dx.doi.org/10.1016/j.neurobiolaging.2008.09.023

Salthouse, T. A. (2012). Does the direction and magnitude of cognitive change depend on initial level of ability? *Intelligence, 40,* 352–361. http://dx.doi.org/10.1016/j.intell.2012.02.006

Salthouse, T. A., Schroeder, D. H., & Ferrer, E. (2004). Estimating retest effects in longitudinal assessments of cognitive functioning in adults between 18 and 60 years of age. *Developmental Psychology, 40,* 813–822. http://dx.doi.org/10.1037/0012-1649.40.5.813

Shephard, R. J. (2003). Limits to the measurement of habitual physical activity by questionnaires. *British Journal of Sports Medicine, 37,* 197–206. http://dx.doi.org/10.1136/bjsm.37.3.197

Skaff, M. M. (2007). Sense of control and health. In C. M. Aldwin, C. L. Park, & A. Spiro (Eds.), *Handbook of health psychology and aging* (pp. 186–209). New York, NY: Guilford Press.

Smith, P. J., Blumenthal, J. A., Hoffman, B. M., Cooper, H., Strauman, T. A., Welsh-Bohmer, K., . . . Sherwood, A. (2010). Aerobic exercise and neurocognitive performance: a meta-analytic review of randomized controlled trials. *Psychosomatic Medicine, 72,* 239–252.

Soederberg-Miller, L., & Lachman, M. E. (1999). The sense of control and cognitive aging. In T. M. Hess & F. Blanchard-Fields (Eds.), *Social cognition and aging* (pp. 17–41). New York, NY: Academic Press. http://dx.doi.org/10.1016/B978-012345260-3/50003-3

Spiro, A., III, & Brady, C. B. (2011). Integrating health into cognitive aging: Toward a preventive cognitive neuroscience of aging. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 66*(Suppl. 1), i17–i25. http://dx.doi.org/10.1093/geronb/gbr018

Stampfer, M. J. (2006). Cardiovascular disease and Alzheimer's disease: Common links. *Journal of Internal Medicine, 260,* 211–223. http://dx.doi.org/10.1111/j.1365-2796.2006.01687.x

Sullivan, A. N., & Lachman, M. E. (2017). Behavior change with fitness technology in sedentary adults: A review of the evidence for increasing physical activity. *Frontiers in Public Health*. Advance online publication. http://dx.doi.org/10.3389/fpubh.2016.00289

Thoemmes, F. (2015). Reversing arrows in mediation models does not distinguish plausible models. *Basic and Applied Social Psychology, 37,* 226–234. http://dx.doi.org/10.1080/01973533.2015.1049351

Turiano, N. A., Chapman, B. P., Agrigoroaei, S., Infurna, F. J., & Lachman, M. (2014). Perceived control reduces mortality risk at low, not high, education levels. *Health Psychology: Official Journal of the Division of Health Psychology, American Psychological Association, 33,* 883–890. http://dx.doi.org/10.1037/hea0000022

Uchino, B. N. (2006). Social support and health: A review of physiological processes potentially underlying links to disease outcomes. *Journal of Behavioral Medicine, 29,* 377–387. http://dx.doi.org/10.1007/s10865-006-9056-5

U.S. National Library of Medicine. (2016). *Investigating gains in neurocognition in an intervention trial of exercise (IGNITE)*. Retrieved from https://clinicaltrials.gov/ct2/show/NCT02875301

Vidoni, E. D., Johnson, D. K., Morris, J. K., Van Sciver, A., Greer, C. S., Billinger, S. A., . . . Burns, J. M. (2015). Dose-response of aerobic exercise on cognition: A community-based, pilot randomized controlled trial. *PLoS ONE, 10,* e0131647. http://dx.doi.org/10.1371/journal.pone.0131647

Ware, J. E. J., Jr., & Sherbourne, C. D. (1992). The MOS 36-item short-form health survey (SF-36): I. Conceptual framework and item selection. *Medical Care, 30,* 473–483. http://dx.doi.org/10.1097/00005650-199206000-00002

White, S., Wójcicki, T., & McAuley, E. (2011). Social cognitive influences on physical activity behavior in middle-aged and older adults. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 67B,* 1–9. http://dx.doi.org/10.1093/geronb/gbr064

White, S. M., Wójcicki, T. R., & McAuley, E. (2012). Social cognitive influences on physical activity behavior in middle-aged and older adults. *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 67,* 18–26. http://dx.doi.org/10.1093/geronb/gbr064

Windsor, T. D., & Anstey, K. J. (2010). Age differences in psychosocial predictors of positive and negative affect: A longitudinal investigation of young, midlife, and older adults. *Psychology and Aging, 25,* 641–652. http://dx.doi.org/10.1037/a0019431

Wingfield, A., Tun, P. A., & McCoy, S. L. (2005). Hearing loss in older adulthood. What it is and how it interacts with cognitive performance. *Current Directions in Psychological Science, 14,* 144–148. http://dx.doi.org/10.1111/j.0963-7214.2005.00356.x

Wolinsky, F. D., Vander Weg, M. W., Martin, R., Unverzagt, F. W., Willis, S. L., Marsiske, M., . . . Tennstedt, S. L. (2010). Does cognitive training improve internal locus of control among older adults? *The Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 65,* 591–598. http://dx.doi.org/10.1093/geronb/gbp117

Zahodne, L. B., Meyer, O. L., Choi, E., Thomas, M. L., Willis, S. L., Marsiske, M., . . . Parisi, J. M. (2015). Externallocus of control contributes to racial disparities in memory and reasoning training gains in ACTIVE. *Psychology and Aging, 30,* 561–572. http://dx.doi.org/10.1037/pag0000042

(*Appendix follows*)

Appendix

Physical Activity Questionnaire

How Often Do You Engage in Vigorous/Moderate/Light Physical Activity?

	Several times a week	Once a week	Once a month	Less than once a month	Never
. . . While at your paid job . . .					
. . . during the summer?					
. . . during the winter?					
. . . While performing chores in and around your home . . .					
. . . during the summer?					
. . . during the winter?					
. . . During your leisure or free time . . .					
. . . during the summer?					
. . . during the winter?					

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