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Self-Reported Mid- to Late-Life Physical and Recreational Activities: Associations with Late-Life Cognition

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Abstract

Objective.—Physical and recreational activities are behaviors that may modify risk of late-life cognitive decline. We sought to examine the role of retrospectively self-reported midlife (age 40) physical and recreational activity engagement – and self-reported change in these activities from age 40 to initial study visit – in predicting late-life cognition.

Method.—Data were obtained from 898 participants in a longitudinal study of cognitive aging in demographically and cognitively diverse older adults (Age: range=49–93 years, M=75, SD=7.19). Self-reported physical and recreational activity participation at age 40 and at the initial study visit were quantified using the Life Experiences Assessment Form. Change in activities was modeled using latent change scores. Cognitive outcomes were obtained annually (range=2–17 years) using the Spanish and English Neuropsychological Assessment Scales, which measures verbal episodic memory, semantic memory, visuospatial processing, and executive functioning.

Results.—Physical activity engagement at age 40 was strongly associated with cognitive performance in all four domains at the initial visit and with global cognitive slope. However, change in physical activities after age 40 was not associated with cognitive outcomes. In contrast, recreational activity engagement – both at age 40 and change after 40 – was predictive of cognitive intercepts and slope.

Conclusions.—Retrospectively self-reported midlife physical and recreational activity engagement were strongly associated with late-life cognition – both level of performance and rate of future decline. However, the data suggest that maintenance of recreational activity engagement (e.g., writing, taking classes, reading) after age 40 is more strongly associated with late-life cognition than continued maintenance of physical activity levels.

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Keywords

Cognitive Aging; Healthy Aging; Exercise; Household Work; Leisure Activities; Hobbies

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Alzheimer's disease is characterized by the accumulation of abnormal levels of amyloid and tau pathology, which causes neurodegeneration and late-life cognitive decline that that unfolds over multiple decades (Sutphen et al., 2015). Current evidence suggests that different risk and protective factors, encountered throughout the lifespan, have the potential to modify Alzheimer's disease burden and associated clinical sequelae (Livingston et al., 2020; Stern et al, 2020). Broadly speaking, some protective factors are believed confer their protection by enhancing resistance and resilience to Alzheimer's disease pathology, where 'resistance' refers to reduced development of brain pathology (e.g., less amyloid burden than expected based on one's age and other risk factors) and 'resilience' refers to the brain's capacity to cope with pathology (e.g., slower cognitive decline than expected based on the degree of neurodegeneration; Arenaza-Urquijo & Vemuri, 2020). Resistance and resilience are proposed to be manifestations of brain reserve, brain maintenance, and cognitive reserve (Stern et al., 2022), all of which may be enhanced by modifiable behavioral and health factors (de Rooij, 2022). Of the many candidate protective factors, participation in physical and recreational activities are two of the most promising, given the robust evidence base in the literature to support their protective effects against late-life cognitive decline (Baumgart et al., 2015; Fratiglioni et al., 2004; Norton et al., 2014). For the purpose of this study, recreational activities are defined as leisure activities that provide intellectual stimulation, increase social contact, and/or support emotional wellbeing.

It has been hypothesized physical activity may initiate biological repair processes in organs including the brain, thus serving to preserve cognitive functioning via promoting brain maintenance (Lieberman et al., 2021). For example, evidence has suggested that midlife physical activity is associated with larger late-life gray matter volumes (Rovio et al., 2010), and that late-life physical activity is associated with a number of positive late-life brain biomarkers, such as larger gray and white matter volumes, less amyloid and tau burden, and increased functional connectivity within the hippocampus (Benedict et al., 2013; Brown et al., 2013; Brown et al., 2018; Eisenstein et al., 2021; Erickson et al., 2010; Steffener et al., 2016).

Past research has also shed some light on the association between mid- to late-life physical activity engagement and late-life cognition. Meta-analyses have found that, overall, higher baseline physical activity is associated with reduced risk of cognitive decline and dementia over follow-ups ranging from 1 to 27 years (Blondell, Hammersley-Mather & Veerman, 2014), and higher physical activity in people over 65 is associated with reduced risk of dementia due to Alzheimer's disease (Beckett, Adern & Rotondi, 2015). Similarly, recreational activity engagement may play a role in protecting against late-life cognitive decline. Mid- and late-life recreational activity participation has been associated with a reduced risk of late-life cognitive decline and dementia (e.g., Akbaraly et al., 2009; Andel et al., 2014; Carlson et al., 2008; Friedland et al., 2001; Lindstrom et al., 2005; Scarmeas et al., 2001; Wilson et al., 2002; Yates et al., 2016), even after accounting for education and occupational complexity (Jonaitis et al., 2013), and late-life interventions to increase recreational activity engagement have positive effects on cognitive performance (e.g., Iizuka et al., 2019).

While the literature broadly supports a protective effect of higher activity levels on late-life cognitive functioning, past research in this area has largely used cross-sectional ratings of activity engagement, either current or retrospective (Benedict et al., 2013; Chang et al., 2010; Guiney et al. 2019; Casaletto et al., 2020), or interventions to experimentally induce short-term changes in activity levels. Although evidence suggests that activity engagement changes throughout the lifespan (e.g., van der Zee et al., 2019; Williams et al., 2020), fewer studies have attempted to quantify the effect of naturalistic changes in activity engagement over the years or decades prior to the measurement of relevant cognitive outcomes (Tolppanen et al., 2015; Wagner et al., 2020). Similarly, previous studies on activity engagement have often measured cognitive outcomes cross-sectionally (Gross et al., 2017; Erickson et al., 2009) or have used relatively simple methods of capturing change, such as observed difference scores or dichotomous variables representing change vs. no change (e.g., Sofi et al., 2011), which do not account for measurement error. Therefore, to gain a more comprehensive understanding of how physical and recreational activities confer protection against late-life cognitive decline, it is important to determine whether changes in these activity levels over an extended time frame – e.g., from midlife to late life – offer any additional predictive value beyond static measures of activity engagement.

Using data from the current cohort, Brewster et al. (2014) found evidence to suggest that self-reported recreational activities at midlife (i.e., age 40) and current (i.e., late-life) together formed a synergistic relationship with late-life cognitive decline, such that slower late-life cognitive decline was associated with high current recreational activities but low midlife recreational activity engagement. This pattern of results was interpreted to suggest that larger decreases in recreational activities after midlife were associated with a more rapid decline in global cognition, after controlling for numerous covariates. In addition, higher initial cognitive status in the domains of semantic memory and executive functioning were predicted by heavy physical activity engagement at midlife. However, the study by Brewster et al. (2014) was limited by its use of sum scores to quantify activity engagement without establishing whether those scores were equally valid at both age epochs.

Thus, the goal of the current study is to examine how retrospectively self-reported physical and recreational activity engagement in midlife, and changes in these activities from midlife to late-life, influence late-life cognitive outcomes. Our study seeks to build upon previous research in several important ways. We will use latent variable modeling to measure self-reported activity engagement, which can ensure that these constructs are measured with equal validity at both age epochs (measurement invariance; Liu et al., 2017). This also allows for latent change score modeling, which provides a direct estimate of change in self-reported activity engagement over time, free from measurement error (McArdle, 2009). Of the few studies in this area that have used longitudinal cognitive outcomes, most have relied upon relatively coarse measures of cognitive status, such as the Mini-Mental State Examination (e.g., Schuit et al., 2001), which may not be psychometrically well-suited for tracking cognitive change over time (e.g., due to ceiling effects). In the current study, we will use an established cognitive factor structure previously validated in this cohort (e.g., Fletcher et al., 2019; Gavett et al., 2018) to investigate cross-sectional and longitudinal cognitive outcomes, i.e., cognitive intercepts and slopes.

Drawing on the information presented above, we hypothesize that both cross-sectional (midlife: age 40) and longitudinal (change from midlife to late-life) self-reported physical and recreational activity engagement will be positively associated with cognitive outcomes. Specifically, we predict that greater self-reported midlife engagement and less self-reported decline in engagement from midlife to late life will predict better cross-sectional cognitive performance (i.e., higher cognitive intercepts), and less rapid decline in cognitive performance (i.e., more positive cognitive slopes).

Method

Participants

Participants were 898 volunteers in the University of California (UC) Davis Aging and Diversity Cohort (ADC), which is a longitudinal sample that contains large proportions of Hispanic/Latinx, Black, and non-Hispanic White older adults. A more detailed description of the cohort, including recruitment, can be found in Hinton et al. (2010). Participants in this study were evaluated and followed within the research program of the UC Davis Alzheimer's Disease Center. Enrollment began in 2001 and a rolling enrollment design was used to build the cohort, with substantial enrollment continuing through 2010. Exclusion criteria included unstable major medical illness, major primary psychiatric disorder, and substance abuse or dependence in the last 5 years. All participants signed informed consent, all human subject involvement was overseen by institutional review boards at UC Davis, the Veterans Administration Northern California Health Care System, and San Joaquin General Hospital in Stockton, California, and the research was completed in accordance with the Helsinki Declaration. Study visits, which occur (approximately) annually, typically require several hours to complete and include comprehensive neuropsychological assessment, neurological examination, and completion of questionnaires. Due to rolling enrollment, there was variability in the total number of evaluations completed by each participant. The participants in the current study had at least two annual study visits where cognition was measured. Clinical diagnosis of participants was made by a consensus committee of experts using standard diagnostic criteria (e.g., Albert et al., 2011; McKhann et al., 2011).

Materials

Self-reported physical and recreational activity participation was measured using the Life Experiences Assessment Form (LEAF; see Brewster et al., 2014). Participants used the LEAF to answer questions about their current physical and recreational activity engagement as well as their retrospectively-rated physical and recreational activity engagement at age 40. For some participants, "current" self-reported activity levels were queried at their baseline visit. For other individuals who had been enrolled prior to implementation of the LEAF, their "current" activity levels were based on the first study visit at which the LEAF was administered. Finally, some participants had discontinued or withdrawn from the parent study before the LEAF was administered; we retained data from these participants in the current study to ensure that our outcomes (cognitive intercepts and slopes) were estimated using as much data as possible. For all participants, self-reported ratings of activity engagement at age 40 were made retrospectively using the same set of questions. If the LEAF was administered more than once to any participant during follow-up study visit(s), only data from the initial administration was used in the current study. Physical activity items on the LEAF ask participants to use a 5-point Likert scale to rate their frequency of activity engagement, ranging from 1 (“Never”) to 5 (“Every day or almost every day”), on tasks described as light work-related tasks, heavy work-related tasks, light house/yard work, vigorous house/yard work, light exercise, and vigorous exercise. Recreational activity items on the LEAF ask about reading, complex cooking, writing, taking classes, performance arts, games or puzzles, cultural events, arts and crafts, socializing, and attendance at clubs or meetings, using the same 5-point Likert scale. Item response categories were collapsed when necessary to avoid sparse cells (i.e., response options that were endorsed by fewer than 10 participants).

Using the current sample data, we estimated the internal consistency reliability of the LEAF scores for both activity types (physical and recreational) and both age epochs (age 40 and current) using the *item.omega* function from the misty (version 0.4.10; Yanagida, 2023) package in R version 4.2.3 (R Core Team, 2023). This function calculates McDonald’s omega reliability coefficient (McDonald, 1999) for categorical data and can account for residual covariances between items (Green & Yang, 2009). The sample reliability statistics are as follows: Age 40 physical activities, $\omega = .66$, 95% CI [.61, .70]; current physical activities, $\omega = .63$, 95% CI [.59, .68]; age 40 recreational activities, $\omega = .67$, 95% CI [.63, .71]; and current recreational activities, $\omega = .68$, 95% CI [.64, .72].

Cognitive functioning was measured using the Spanish and English Neuropsychological Assessment Scales (SENAS). The SENAS has undergone extensive development as a battery of cognitive tests relevant to cognitive aging that allow for valid comparisons across racial, ethnic, and language groups (Mungas et al., 2004; 2005; Mungas, Reed, Marshall, & González, 2000; Mungas, Reed, Tomaszewski Farias, & DeCarli, 2005; Mungas, Widaman, Reed, & Tomaszewski Farias, 2011). Development and validation of the SENAS used modern psychometric methods to ensure highly reliable measurement across a diverse range of abilities and ages, and across both Spanish and English speakers. The SENAS yields four psychometrically-matched composite scores – verbal episodic memory, semantic memory, spatial, and executive functioning – that are normally distributed and free from floor and ceiling effects. The episodic memory composite score is created using a multi-trial word-list-learning task (Mungas et al., 2004). Semantic memory is assessed using object-naming and picture association tasks. Executive functioning scores represent a combination of verbal fluency (semantic, phonemic) and working memory (backward digit span and visual span, list sorting) tasks. The SENAS Spatial Localization scale was used to derive the Spatial composite score; this task measures perception and reproduction of increasingly complex two-dimensional spatial relationships. The SENAS measures were administered at all evaluations. Administration procedures, measure development, and psychometric characteristics of the SENAS battery are described in more detail elsewhere (Mungas et al., 2004).

Data Analysis

Physical and Recreational Activities—For each activity type, two latent variables were derived from the LEAF data: (1) activity engagement at age 40 and (2) change in activity engagement from age 40 to current. Latent change score models (McArdle, 2009) were used to estimate these age-40 and change factors for physical (Figure 1) and recreational (Figure 2) activities. To account for differences in time elapsed between age 40 and current, participant age (centered at 70) was included as a covariate in these models. Because physical and recreational activity engagement were measured using self-report, which is susceptible to bias introduced by the presence of cognitive impairment (i.e., cognitively impaired individuals may be less capable of reliably reporting on their personal history), we sought to determine whether the models used to estimate these activities were invariant to cognitive status. Before running the latent change score models, we also established that physical and recreational activities could be modeled with equal validity at both age epochs (age 40 and current). A description of our approach to establishing the time invariance of these models is provided in an electronic supplement.

Cognition—Cognitive performance outcomes were modeled using separate but correlated latent intercepts for four constructs – verbal episodic memory, semantic memory, spatial ability, and executive functioning – along with a single latent slope factor representing rate of change in global cognitive functioning. This factor structure has provided the best fit to our longitudinal cognitive data in numerous other studies (e.g., Fletcher et al., 2018; Gavett et al., 2018); in particular, our use of a global cognitive slope is consistent with literature suggesting that much of the variance in late-life cognitive decline can be attributed to a general change factor (e.g., Tucker-Drob, Brandmaier, & Lindenberger, 2019).

Hypothesis Testing—We created two integrated structural models – one for physical activities and the other for recreational activities – to test our hypotheses about the degree to which late-life cognition is influenced by midlife activity participation and changes in activity participation from midlife to late-life. This model was analyzed using the Bayes estimator (with default priors) within the multilevel modeling framework of Mplus version 8.6 (Muthén & Muthén, 2021). In the within part of the model (Figure 3A), we estimated intercepts and slopes for each of the four cognitive domains as a function of time. The cognitive test scores were regressed on a dichotomous indicator of whether participants had participated in neuropsychological assessment at a prior study visit to account for practice effects. The cognitive scores were also regressed on a previous evaluation by Spanish language interaction term because past research in this cohort has shown that the magnitude of previous evaluation effects differs between Spanish and English speakers (Brewster, et al., 2014; Early et al., 2013; Melrose et al., 2015). In the between part of the model (Figure 3B), a global cognitive slope factor was incorporated and the five primary outcome variables (4 cognitive intercepts and 1 cognitive slope) were regressed on latent activity participation at age 40, latent change in activity participation from age 40 to the current visit, and a number of observed covariates. These covariates included age (years centered at 70), education (years centered at 12), and dichotomous indicator variables representing sex (reference = female), referral source (0 = community, 1 = clinic), Black/African American racial identification (0 = no, 1 = yes), Latinx or Hispanic ethnic identification (0 = no, 1 =

yes), other ethnic/racial identification (0 = no, 1 = yes), and primary language (0 = English, 1 = Spanish). See the Supplemental material for more details about the multilevel analyses.

Results

Ages in this sample ranged from 49 to 93 years, education ranged from 0–20 years, and the number of study visits ranged from 2–17. Additional participant demographics are provided in Table 1. We also show descriptive data in Table 1 stratified by whether or not participants ever completed the LEAF questionnaire. The results show that those who never completed the LEAF were older, less educated, more cognitively impaired (both in terms of cognitive performance and in terms of frequency with which a diagnosis of MCI or Dementia was made), and more likely to be a clinical – rather than community – referral into the parent study. Therefore, by retaining participants without LEAF data in the primary analyses, our cognitive outcomes (intercepts and slope) are more representative of the full range of diversity in the population from which this cohort was recruited.

The fits of the latent change score models were satisfactory, especially for the physical activities model (Figure 1), χ^2 (df = 58) = 143.97, $p < .01$, CFI = 0.955, TLI = 0.940, RMSEA = 0.049 (95% CI [0.039, 0.059]). Fit was more modest, but acceptable, for the recreational activities model (Figure 2), χ^2 (df = 193) = 472.40, $p < .01$ CFI = 0.904, TLI = 0.895, RMSEA = 0.049 (95% CI [0.044, 0.055]). Measurement invariance testing was performed to determine whether physical and recreational activity engagement could be modeled equally well in cognitively impaired (i.e., MCI and dementia) and cognitively intact participants. Full results are shown in the supplementary material. To summarize here, there was mixed evidence to support the scalar invariance of the physical and recreational activities models across groups defined by cognitive impairment status. For both activity factors, because the scalar invariance models had reasonably good absolute fit, we proceeded with our planned analysis. Because we used a Bayesian estimator to fit the full structural model shown in Figure 3, traditional model fit statistics were not available. However, the models reached convergence as determined by a potential scale reduction factor (Gelman & Rubin, 1992) that reached a point of stability (i.e., < 1.1) for the second half of all sampling iterations.

The multilevel modeling results are presented in Tables 2 (physical activities) and 3 (recreational activities). Retrospectively self-reported physical activity engagement at age 40 was a strong predictor of all cognitive outcomes (the four domain-specific intercepts and the global slope); in contrast, change in self-reported physical activity engagement from age 40 to current (adjusted for amount of time elapsed) was not a salient predictor of any cognitive outcome. On the other hand, not only was retrospectively self-reported age 40 recreational activity engagement a predictor of all cognitive outcomes, but change in self-reported recreational activities over time was a strong predictor of all cognitive outcomes as well. A visual depiction of these results is shown in Figure 4, which is based on a hypothetical reference participant, representing a 70-year-old non-Hispanic White English-speaking woman with 12 years of education who was a community referral.

Discussion

In recent decades, it has become increasingly well-established that Alzheimer's disease pathology – namely, the accumulation of amyloid and tau pathologies – begins to unfold decades before clinical signs and symptoms emerge (Sutphen et al., 2015). Therefore, it is important to identify modifiable protective factors that can be intervention targets earlier in life. Previous research has established the importance of several lifestyle variables that are associated with greater age-related resilience against neurodegeneration and cognitive decline, including engagement in physical and recreational activities (Baumgart et al., 2015; Fratiglioni et al., 2004).

Past research in this area has tended to examine cross-sectional activity ratings or short-term experimental interventions, whereas few studies have attempted to examine naturalistic changes in activity engagement over the years or decades prior to the measurement of late-life cognition (Tolppanen et al., 2015; Wagner et al., 2020). Similarly, past research has tended to use outcome variables like cross-sectional cognitive performance, dichotomous indicators of cognitive decline, or conversion to dementia; as such, less is known about how prior activity engagement influences the rate of change in late-life cognition (Schuit et al., 2001; Sofi et al., 2011; Wagner et al., 2020). We addressed these gaps in the literature by using rigorous methods for measuring not only static self-reported physical and recreational activity engagement – but change in these self-reported behaviors over time – along with high quality longitudinal cognitive outcome data. We hypothesized that both cross-sectional (midlife: age 40) and longitudinal (change from midlife to late-life) self-reported physical and recreational activity engagement would be positively associated with cognitive outcomes, i.e., cognitive intercepts and slopes.

Our hypothesis was partially supported: more retroactively self-reported activity engagement at midlife – both physical and recreational – was predictive of better late-life cognitive intercepts and slopes. However, we found a marked difference when examining *change* in self-reported activity engagement as a predictor of late-life cognition. After controlling for retroactively self-reported midlife activity levels, maintaining or even increasing one's self-reported engagement in recreational activities (e.g., intellectually stimulating activities) over time was associated with higher baseline cognition and less rapid cognitive decline in later life. In contrast, change in self-reported physical activity after midlife was not a positive predictor of late-life cognitive decline. These findings are consistent with those of Brewster et al. (2014), though we extended upon their study by using sophisticated latent variable methods, a larger sample size, a longer period of follow-up, and more comprehensive cognitive outcome data. Our findings are also consistent with previous studies that have found a positive association between mid- and late-life activity participation and late-life cognition (e.g., Akbaraly et al., 2009; Andel et al., 2015; Carlson et al., 2008, Friedland et al., 2001; Lindstrom et al., 2005; Scarmeas et al., 2001; Wilson et al., 2002; Yates et al., 2016).

Importantly, mid- and late-life participation in cognitively stimulating activities has been shown to be associated with independently derived and validated measures of late-life cognitive reserve (Reed et al., 2011). Reserve in that study was operationalized as cognitive function not explained by comprehensive measures of neuropathology, and thus, these results suggest that cognitively stimulating activities promote resilience to negative effects of brain pathology on cognition. Although the current study does not address whether the protective effect of recreational activity engagement on cognition is mediated via increased cognitive reserve, our findings contribute more evidence to the extant literature suggesting that higher levels of recreational activity engagement are associated with better late-life cognition and slower cognitive decline. We also note that a novel conclusion arising from the current study is that change in recreational activities over a period of decades may be a very important target for interventions designed at promoting late-life cognition, thus building on similar evidence obtained from shorter term intervention studies (Iizuka et al., 2019). These findings suggest that community-based interventions designed to increase access to recreational activities – especially in middle age and later – could make an important contribution to public health.

This study has several limitations. First, self-reported ratings of activity engagement at age 40 were made retrospectively. Retrospective ratings of past behaviors can be unreliable and subject to bias (e.g., Fransson et al., 2008). In particular, individuals with lower cognitive functioning – an outcome variable used in the current study – may be more likely to make mistakes when answering questions about their personal history (Schneider et al., 2021). Even contemporaneous self-report of current activity levels may be susceptible to reporting bias (Adams et al., 2005). We sought to investigate whether our models used to measure self-reported physical and recreational activity engagement were invariant to cognitive status. Those results, reported in Supplemental material, were supportive of measurement invariance for recreational activities, but mixed for physical activities. Thus, it is possible that the results pertaining to physical activities could be influenced by degree to which cognitively impaired individuals can make valid self-reports about their activity engagement. Similarly, the fit of the recreational activities measurement model to the data was modest. Finding more optimal methods to measure lifespan changes in these activities is an area for continued improvement.

Future research can build upon these results by measuring activity engagement directly and prospectively (e.g., using accelerometers or similar technology). In this study, change was modeled using latent change scores derived from two time points and, therefore, cannot account for nonlinear changes – which may provide a better fit to the data (van der Zee et al., 2019; Wagner et al., 2019) – in activity engagement over time. Finally, our results were derived from two separate models for physical and recreational activity engagement, which essentially treats these two types of activities as statistically independent. However, it is likely that they share some variance with one another, although the degree to which they share variance may depend on population-level characteristics (e.g., Casaletto et al., 2020). Because we did not jointly estimate the influence of both physical and recreational activities together in the same model, it is possible that our results would have changed if all predictors were used in a single model. However, this was statistically untenable given the complexity of the models.

The current results were derived from observational data and are limited with respect to causal inferences. Participants were not randomly selected, nor were they randomly assigned to different levels of activity engagement; in other words, participants self-selected their own physical and recreational activity levels. It is possible that one or more unmeasured variable(s), such as early-life intellectual functioning (Kumpulainen et al., 2017) or socioeconomic status (Hua & Brown, 2022), may have predisposed some individuals to be more physically and recreationally active throughout the lifespan, and also predisposed them toward lower risk of cognitive decline through pathways that were (largely) independent from physical and recreational activity participation (e.g., better nutrition, better access to health care, less exposure to environmental toxins). In addition, we cannot exclude reverse causality as a possible explanation for some of our results, as activity engagement may decline as a result of early declines in cognitive functioning (e.g., Sabia et al., 2017). Therefore, it is possible that some of our participants may have experienced cognitive decline prior to study enrollment, causing them to become less physically and/or recreationally active. However, because many known modifiable risk factors for dementia can be positively influenced by physical and recreational activity participation – such as depression, diabetes, hypertension, obesity, and social isolation (Livingston et al., 2020) – there are several plausible mechanisms by which mid- and late-life activity engagement could reasonably be assumed to exert a causal influence over late-life cognition (Huai et al., 2013; Schuch et al., 2016; Teh et al., 2019; Wu et al., 2009; Zhu et al., 2022). Randomized controlled trials may be needed to fully elucidate these causal pathways.

Despite these limitations, the current study has many strengths. We took care to ensure that physical and recreational activity engagement – and their changes – could be measured with equal validity over both self-reported time epochs. We used a well-established latent change score approach to measuring change in activity levels, which ensures that our predictor variables are minimally influenced by measurement error (McArdle, 2009). Extensive, well-validated neuropsychological outcome data were available for participants across many study visits, thus providing excellent characterization of cognitive aging trajectories. The sample was also quite diverse; the ethnoracial composition of our sample was approximately 25% black and 24% Hispanic/Latinx. Our sample was also diverse in terms of cognitive functioning, clinic vs. community referral source, and primary language spoken. These elements of diversity allow for generalization of our results to a broad segment of the older adult population and allow inferences to be made about a broad spectrum of cognitive functioning, ranging from cognitively healthy to dementia.

We did not conduct separate analyses stratified by ethnic, racial, or language groups. It is possible, however, that physical and recreational activity participation – or one's self-report of such – could be influenced by cultural or linguistic factors. Future research may wish to explore whether any such differences exist, and if they are relevant to late-life cognition. This same comment could also be made about sex differences. The vast majority of women will experience menopause between 40 (the age used as the first indicator of activity engagement in this study) and 75 (the average baseline participant age in the current study) years of age, thus highlighting the importance of considering sex differences when studying lifestyle and behavior changes across the second half of the lifespan.

In this study, we provide evidence to suggest that self-reported midlife (age 40) engagement in physical and recreational activities is predictive of late-life cognitive functioning. Further, self-reported change in cognitively stimulating recreational activities – more so than change in physical activities – was also highly predictive of future cognitive decline. Our study adds to this large and well-developed body of literature, using a rigorous longitudinal, latent-variable modeling approach to measuring cognitive outcomes and the predictor variables of interest to address how life-course trajectories of recreational and physical activity are associated with late-life cognitive decline. These results, in the context of the broader literature, suggest that both types of activity engagement may contribute to late-life cognitive health when implemented at midlife or perhaps even earlier. Some researchers in this area have theorized that the protective effects of recreational activity engagement on late-life cognition are mediated by cognitive reserve (e.g., Shatenstein et al., 2015). Testing this hypothesized mediation pathway would be an important next step to determine whether midlife recreational activity participation – and change in recreational activity participation beyond age 40 – can in fact build cognitive reserve and, in turn, offer resilience against late-life brain changes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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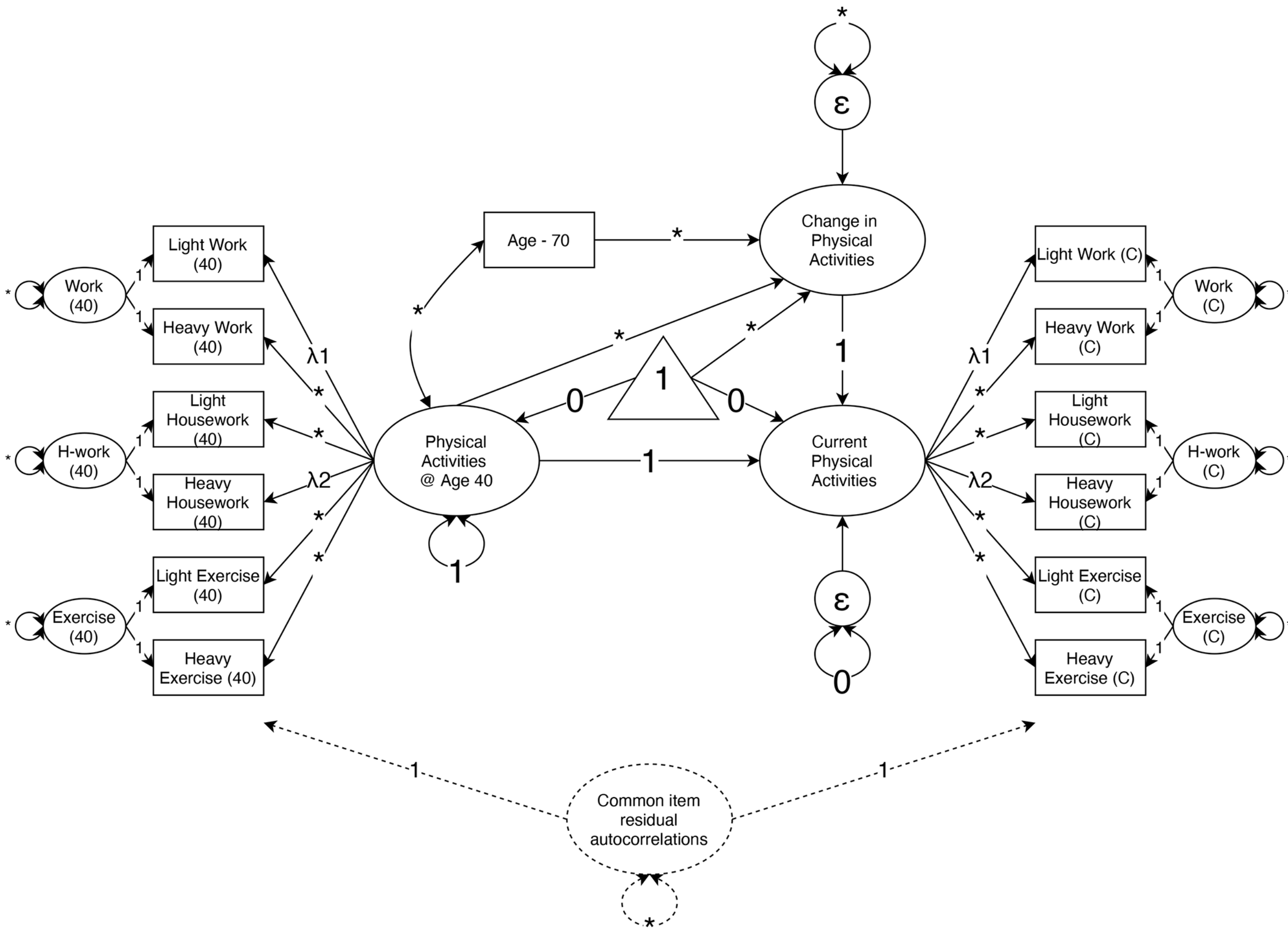

Figure 1.

Latent change score model for physical activities. Arrows labeled with λ indicate that the factor loadings for the corresponding indicators were constrained to be equal across age epochs. Asterisks indicate freely estimated parameters. The residual autocorrelations between the same indicator variables (e.g., light work) at age 40 and current (C) were modeled as one latent variable per item pair, but only shown once (in dashed lines) for simplicity.

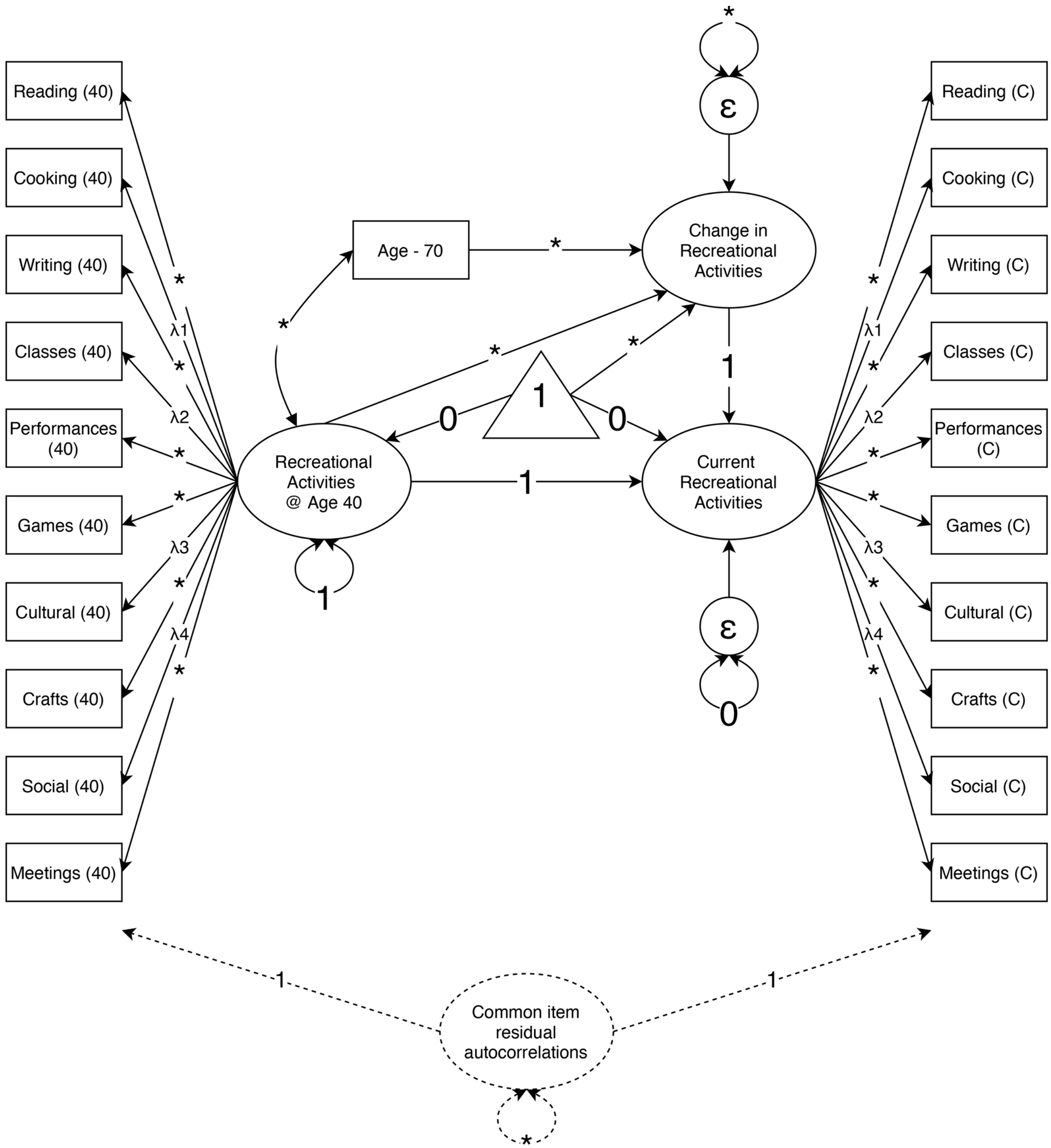

Figure 2.

Latent change score model for recreational activities. Arrows labeled with λ indicate that the factor loadings for the corresponding indicators were constrained to be equal across age epochs. Asterisks indicate freely estimated parameters. The residual autocorrelations between the same indicator variables (e.g., reading) at age 40 and current (C) were modeled as one latent variable per item pair, but only shown once (in dashed lines) for simplicity.

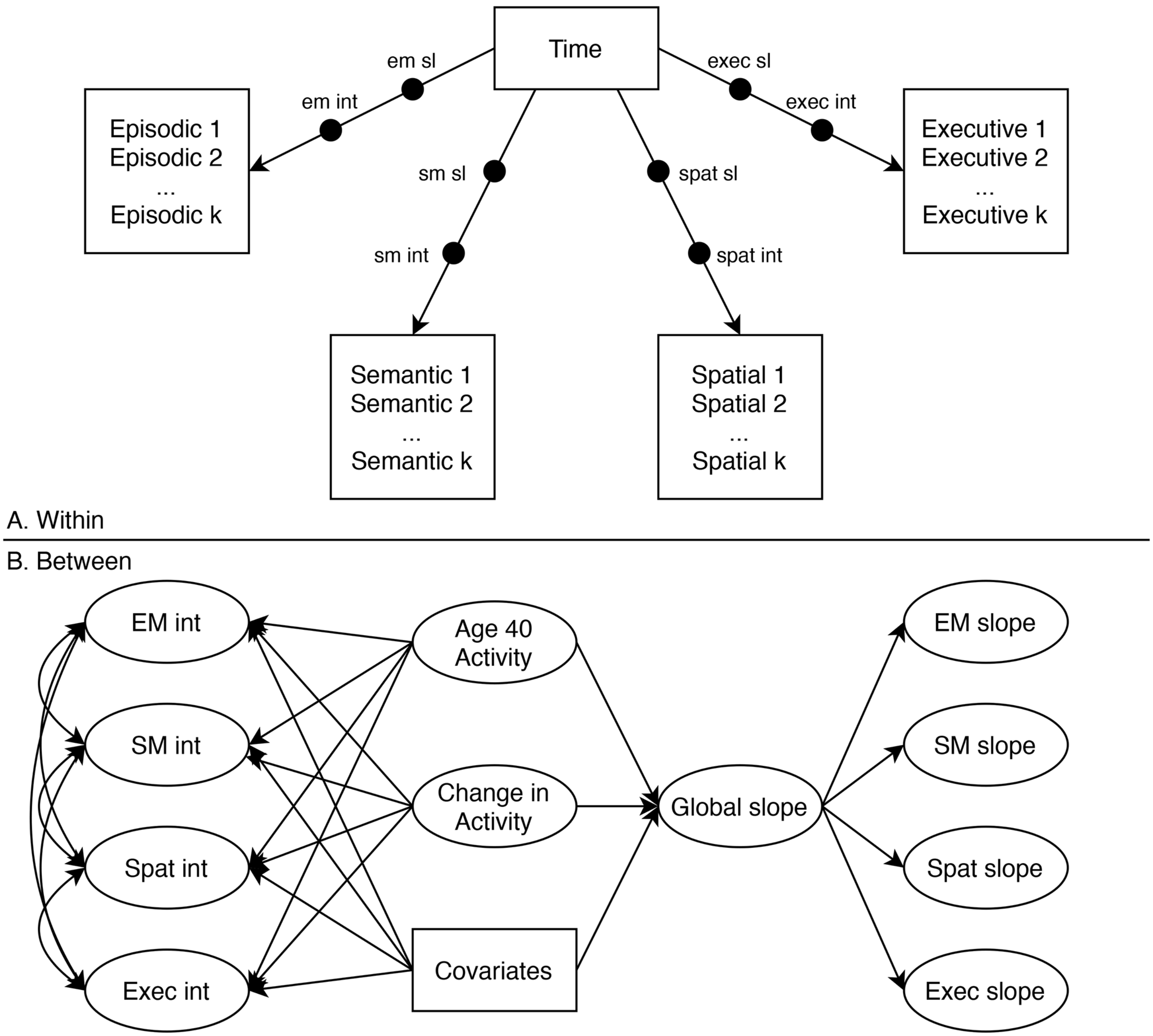

Figure 3.

Multilevel model path diagram showing illustrating our approach to hypothesis testing. In the within part of the model (panel A), domain-specific random intercepts and slopes are defined as a function of time. In the between part of the model (panel B), domain-specific cognitive intercepts and the global cognitive slope are regressed on activity factors (age 40 and change) and covariates.

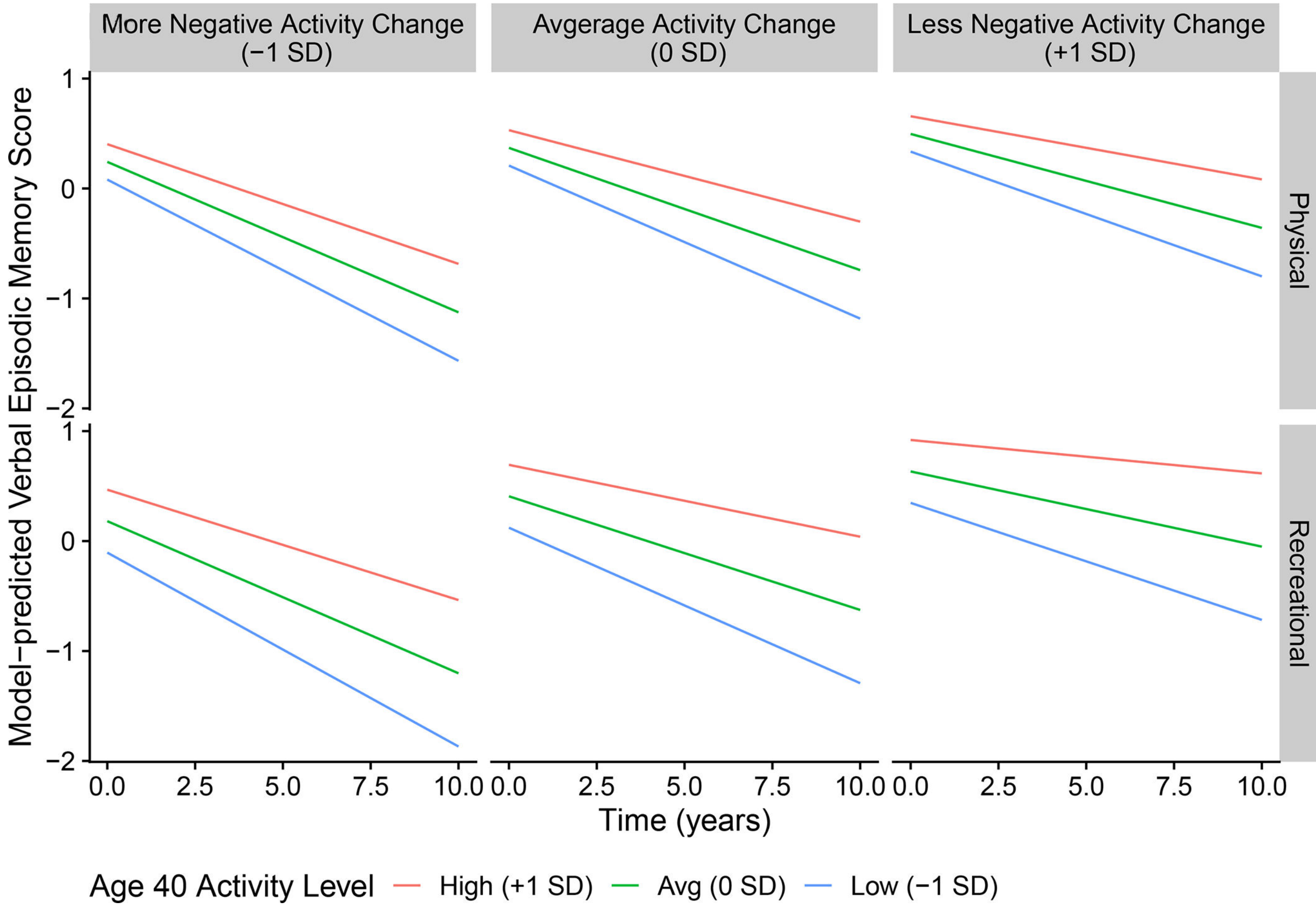

Figure 4.

Model-predicted verbal episodic memory scores plotted as a function of time (x-axis), activity level at age 40 (colored lines), change in activity level over time (vertical facets), and activity type (horizontal facets). Data are based on a hypothetical 70-year-old non-Hispanic White English-speaking woman with 12 years of education who was a community referral (reference participant).

Table 1.

Participant demographics at initial visit

Variable	Total Sample	With LEAF	Without LEAF	Difference
n	898	614	284	
Age; M (SD)	75.05 (7.19)	74.59 (7.08)	76.04 (7.34)	Yes
Education; M (SD)	13.58 (4.43)	14.09 (4.10)	12.47 (4.90)	Yes
Male sex; n (%)	350 (39.0%)	231 (37.6%)	119 (41.9%)	No
Spanish language; n (%)	117 (13.0%)	73 (11.9%)	44 (15.5%)	No
Clinic referral; n (%)	235 (26.2%)	135 (22.0%)	100 (35.2%)	Yes
White/Caucasian; n (%)	413 (46.0%)	276 (45.0%)	137 (48.2%)	No
Black/African American; n (%)	226 (25.2%)	157 (25.6%)	69 (24.3%)	No
Latinx/Hispanic; n (%)	213 (23.7%)	148 (24.1%)	65 (22.9%)	No
Other race/ethnicity; n (%)	46 (5.1%)	33 (5.4%)	13 (4.6%)	No
Clinical diagnosis				Yes
Cognitively normal; n (%)	508 (56.6%)	409 (66.6%)	99 (34.9%)	
MCI; n (%)	264 (29.4%)	149 (24.3%)	115 (40.5%)	
Dementia; n (%)	95 (10.6%)	39 (6.4%)	56 (19.7%)	
No diagnosis; n (%)	31 (3.5%)	17 (2.8%)	14 (4.9%)	
Number of study visits; M (SD)	5.15 (3.31)	5.75 (3.58)	3.87 (2.12)	Yes

Note. LEAF = Life Experiences Assessment Form; MCI = mild cognitive impairment.

Difference column indicates whether the ‘With LEAF’ and ‘Without LEAF’ subgroups differ significantly (a = .05) on the chosen variable.

Table 2.

Physical activities model results

Outcome	Predictor	Estimate	Posterior SD	95% CrI
EM Intercept	PA @ Age 40	0.161 *	0.051	[0.059, 0.257]
EM Intercept	Δ PA	0.089	0.064	[−0.023, 0.229]
SM Intercept	PA @ Age 40	0.192 *	0.051	[0.093, 0.293]
SM Intercept	Δ PA	0.039	0.065	[−0.094, 0.166]
VS Intercept	PA @ Age 40	0.165 *	0.055	[0.058, 0.275]
VS Intercept	Δ PA	0.018	0.070	[−0.129, 0.146]
EF Intercept	PA @ Age 40	0.152 *	0.052	[0.049, 0.254]
EF Intercept	Δ PA	0.058	0.064	[−0.064, 0.190]
Global Slope	PA @ Age 40	0.028 *	0.010	[0.009, 0.046]
Global Slope	Δ PA	0.018	0.012	[−0.003, 0.043]

Note. EM = episodic memory; SM = semantic memory; VS = visuospatial; EF = executive functioning; PA = physical activities; Δ PA = change in physical activities; CrI = credible intervals.

* 95% credible intervals of the posterior distribution do not include 0.

Table 3.

Recreational activities model results

Outcome	Predictor	Estimate	Posterior SD	95% CrI
EM Intercept	RA @ Age 40	0.286 *	0.043	[0.204, 0.373]
EM Intercept	Δ RA	0.265 *	0.054	[0.164, 0.378]
SM Intercept	RA @ Age 40	0.324 *	0.041	[0.245, 0.405]
SM Intercept	Δ RA	0.195 *	0.052	[0.096, 0.303]
VS Intercept	RA @ Age 40	0.267 *	0.044	[0.181, 0.354]
VS Intercept	Δ RA	0.178 *	0.057	[0.069, 0.293]
EF Intercept	RA @ Age 40	0.292 *	0.040	[0.214, 0.372]
EF Intercept	Δ RA	0.172 *	0.052	[0.073, 0.279]
Global Slope	RA @ Age 40	0.038 *	0.008	[0.022, 0.055]
Global Slope	Δ RA	0.041 *	0.010	[0.023, 0.061]

Note. EM = episodic memory; SM = semantic memory; VS = visuospatial; EF = executive functioning; RA = recreational activities; Δ RA = change in recreational activities; CrI = credible intervals.

* 95% credible intervals of the estimate do not include 0.