Social Participation Predicts Cognitive Functioning in Aging Adults Over Time: Comparisons with Physical Health, Depression, and Physical Activity

Kyle Bourassa, Molly Memel, Cindy Woolverton, David A. Sbarra

Department of Psychology, University of Arizona

In Press – Accepted August 4th, 2015 – ***Aging and Mental Health***

Acknowledgements: This paper uses data from SHARE wave 4 release 1.1.1, as of March 28th 2013, and SHARE wave 1 and 2 release 2.6.0 as of November 29th 2013. The SHARE data collection has been primarily funded by the European Commission through the 5th Framework Programme (project QLK6-CT-2001-00360 in the thematic programme Quality of Life) through the 6th Framework Programme (projects SHARE-I3, RII-CT-2006-062193, COMPARE, CIT5-CT-2005-028857, and SHARELIFE CIT4-CT-2006-028812) and through the 7th Framework Programme (SHARE-PREP, N° 211909, SHARE-LEAP, N° 227822 and SHARE M4, N° 261982). Additional funding from the U.S. National Institute on Aging (U01 AG09740-13S2, P01 AG005842, P01 AG08291, P30 AG12815, R21 AG025169, Y1-AG-4553-01, IAG BSR06-11 and OGHA 04-064) and the German Ministry of Education and Research as well as from various national resources is gratefully acknowledged (see www.share-project.org for a full list). Correspondence can be directed to Kyle Bourassa, 1503 E. University Blvd., Bldg #68, Rm. 312. Tucson, AZ 85721-0068, kylebourassa@email.arizona.edu, or (520) 626-6426.

Abstract

Objectives: Several risk and protective factors are associated with changes in cognitive functioning in aging adults — including physical health, depression, physical activity, and social activities — though the findings for participation in social activities are mixed. This study investigated the longitudinal association between social participation and two domains of cognitive functioning, memory and executive function. A primary goal of our analyses was to determine whether social participation predicted cognitive functioning over-and-above physical health, depression, and physical activity in a sample with adequate power to detect unique effects. **Method:** The sample included aging adults (N = 19,832) who participated in a large, multi-national study and provided data across six years; split into two random subsamples. Unique associations between the predictors of interest and cognitive functioning over time and within occasion were assessed in a latent curve growth model. **Results:** Social participation predicted both domains of cognitive functioning at each occasion, and the relative magnitude of this effect was comparable to physical health, depression, and physical activity level. In addition, social participation at the first time point predicted change in cognitive functioning over time. The substantive results in the initial sample were replicated in the second independent subsample. **Conclusion:** Overall, the magnitude of the association of social participation is comparable to other well-established predictors of cognitive functioning, providing evidence that social participation plays an important role in cognitive functioning and successful aging.

Keywords: Cognition; social participation; depression; physical health; physical activity

Social Participation Predicts Cognitive Functioning in Aging Adults Over Time: Comparisons with Physical Health, Depression, and Physical Activity

Aging adults make up an increasing proportion of the population of developed countries (Restrepo & Rozental, 1994). With this generational shift, exploring how to age successfully – with low levels of disability, high cognitive and physical functioning, and high activity level (Depp & Jeste, 2005; Rowe & Kahn, 1997) – is essential to ensure the highest quality of life for aging adults. Cognitive functioning is a primary aspect of successful aging and although cognitive decline is common in older adults, there exists a high degree of variability in the rate of changes people experience (Fillit et al. 2002; Park, O'Connell, & Thomson, 2003). A variety of important individual characteristics, including physical health (Perlmutter & Nyquist, 1990; Zelinkski, Crimmins, Reynolds, & Seeman, 1998), depression (Ownby, Crocco, Acevedo, John, & Loewenstein, 2006), physical activity (Heyn, Beatriz, Abreu, & Ottenbacher, 2004; Sofi, et al., 2011), and social activity (James, Wilson, Barnes, & Bennett, 2011; Zunzunegui, Alvarado, Del Ser, & Otero, 2003) are reliably associated with variability in cognitive decline. Questions remain, however, about how these variables operate together and whether some, but not others, are uniquely associated with cognition over time.

This paper focuses on social participation – a construct that broadly captures people's involvement in social activities – and its association with cognitive functioning in aging adults. In contrast to measures of social support, which typically focus on the subjectively reported type, frequency, and extent of support, social participation indexes involvement in social activities (Berkman & Glass, 2000). Social participation involves a wide of array of possible activities, but common examples include religious groups, volunteer groups, or social or sports clubs.

Participation in social activities is positively associated with mental (Croezen, Avendano, Burdorf, & van Lenthe, 2015) and physical health (Lindström, Moghaddassi, & Merlo, 2004).

There is emerging evidence that social activities are associated with cognition across the lifespan (Seeman et al., 2010), and that this association appears especially strong in aging adults (Fratiglioni, Paillard-Borg, & Winblad, 2004; James, Wilson, Barnes, & Bennett, 2011). Similarly, perceived social isolation (loneliness) is associated with greater risk for cognitive decline (Cacioppo & Hawkley, 2009). When tested longitudinally, however, there is mixed evidence as to whether social activity predicts cognitive decline. For example, an analysis of four longitudinal studies by Brown et al. (2012) found cognition and social activity were related at baseline assessment, but that social activity did not predict change in cognition. McGue and Christensen (2007) also found some evidence that twins' nonshared social activities predict baseline cognitive functioning, however, genetic variation explained the change in cognition over time. Similarly, in a Baltimore-based longitudinal sample, social networks were related to cognition cross-sectionally, but not over time (Green, Rebok, & Lyketos, 2008).

In contrast, other studies have identified longitudinal links between social activity and cognition. For example, earlier levels of social engagement predicted later cognition in a study of Spanish aging adults (Zunzunegui et al., 2003). Similarly, Taiwanese aging adults who participated in more social activities had higher scores on a mental status questionnaire (Glei et al., 2005). Different aspects of social relationships may also differentially affect aging adults' cognition. For example, social activity and social support predict global cognition, but the size of one's social network does not (Krueger et al., 2009). Socioemotional selectivity theory would suggest that aging adults benefit from the frequency of deeper interpersonal relationships, rather than the mere existence of broad social networks (Cartensen, Issacowitz, & Charles, 1999).

Fratiglioni et al. (2004) outlined two biologically plausible mechanisms for how social activities may protect against dementia in particular – one based on cognitive-reserve and enrichment and the other on stress levels. These same mechanisms may have relevance for cognitive decline more generally. The cognitive enrichment hypothesis, derived from cognitive reserve theory (Scarmeas & Stern, 2003), posits that mentally-stimulating environments help maintain cognitive capacity over time (Hertzog, Kramer, Wilson, & Lindenberger, 2008). Stimulating environments can induce neurogenesis (Fillit et al, 2002), even into older age (Churchill et al., 2002), and social participation is one index of exposure to cognitively demanding social environments. Participation in social activities presents a rich opportunity for older adults to experience dynamic and engaging environments that better maintain cognition.

In comparison, the stress – or neurotoxicity – hypothesis suggests that people with higher levels of social activities have lower levels of psychological stress. Psychological stress is associated with physiological response profiles, including higher levels of catecholamines and glucocorticoids, that can have long-lasting health effects and result in neuronal changes (e.g., loss of dendritic spines and neuronal cell death) that impair cognitive functioning (Lupien, McEwen, Gunnar, & Heim, 2009). Prior research has established that aging adults with more loneliness and less social integration face increased psychological distress, such as depression (Glass, De Leon, Bassuk, & Berkman, 2006). In addition, loneliness levels predict increased levels of cortisol in aging adults the following day (Adam, Hawkley, Kudielka, & Cacioppo, 2006), fitting a stress-induced physiological response profile. From this perspective, social participation could protect against cognitive decline in a manner similar to the well-known effects of social support on risk for other morbidities and mortality (see Uchino, 2004).

Competing Predictors and Unique Associations

There are a variety of alternative risk and protective factors for cognitive decline in later life, including lower health (Perlmutter & Nyquist, 1990; Zelinkski, Crimmins, Reynolds, & Seeman, 1998) and higher levels of depression (Ownby, Crocco, Acevedo, John, & Loewenstein, 2006) and less physical activity (Heyn, Beatriz, Abreu, & Ottenbacher, 2004; Sofi, et al., 2011). It is possible that health status, depression, physical activity and social participation are not uniquely predictive of cognition, but instead share common pathways. For example, in addition to predicting cognitive decline, physical health and depression are highly correlated (Beekman et al., 1997; Geerlings, Beekman, Deeg, & Van Tilburg, 2000). A decline in health could result in increased depressive symptoms, which then affect cognitive ability. Social participation may act in conjunction with alternative predictors as well. For example, people who are less healthy may unable to attend social functions, or those that are more depressed may seek out fewer social activities. It is equally plausible, however, that participation in social activities presents unique opportunities – above and beyond the effect of health, depression, and physical activity – for aging adults to engage in cognitively demanding tasks that maintain cognitive functioning (Fratiglioni et al., 2004; Salthouse, 1991).

The Present Study

The present study had two primary aims. First, using data from a large, multi-national sample of aging adults, we sought to evaluate the strength of the association between social participation and two domains of cognitive functioning over time, memory and executive function. Second, we sought to determine if social participation was associated with cognitive functioning in a unique and independent manner after statistically accounting for three well-established predictors of cognitive decline: physical health, depressive symptoms, and physical activity. To achieve these aims, we examined the nature of cognition over time in a latent curve

growth model (LCGM) using data from the Survey of Health, Ageing, and Retirement in Europe (SHARE) study. The large multi-national sample of aging adults (N = 19,832) with longitudinal data presents a rich opportunity to examine competing predictors of change in cognitive functioning over time. We hypothesized that social participation would uniquely predict cognition over time when including physical health, depressive symptoms, and physical activity level as alternative predictors. Finally, we explored whether the magnitude of the social participation and cognitive measures association rivaled that of the alternative predictors.

Method

Participants

The SHARE dataset has four waves of data collection (2004-2005; 2006-2007; 2008-2009; 2011-2012); three panel waves (2004, 2006, and 2010) with six additional waves of data planned (see Börsh-Supan et al., 2013). Participants were selected from 19 European Union countries (Austria, Belgium, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Poland, Portugal, Sweden, Slovenia, Spain, Switzerland) and Israel, with over 86,000 unique participants ages 50 or older. Six countries (Ireland, Israel, Hungary, Portugal, Slovenia, and Estonia), however, did not participate in more than a single wave and are not included in the study sample. Participants from earlier waves were contacted for participation in subsequent waves and the average retention rate of the study for the first four waves was 81%. The SHARE questionnaires were first developed in an English template, which was then adapted to the primary language of participating countries by teams within each country. The translation process, described in more detail by Harkness (2005), involved multiple revisions, professional review, and expert consultation to ensure appropriate translation of survey

assessments. The full range of languages completed by more than 1% of participants is listed in Table 1.

The data collection incorporated a variety of variables capturing participants' psychological states, physical health, and cognition. Only the initial participant from each household with at least two complete waves of data was included in the sample (N = 19,832). The original sample included a total of 85,783 people, of which 53,985 only had a single wave of data from T0, T1, and T3, and were excluded. Of the remaining 29,555 participants with two waves of data, 9,723 people were identified as sharing the same household as primary respondents and were excluded to maintain independence within the sample. Compared to people who were excluded due to only having one assessment, people in the current study had significantly lower memory (*Cohen's d* = 0.09), lower executive function (d = 0.04), higher levels of social participation (d = 0.11), were less physically active (d = 0.06), rated themselves as more physically healthy (d = 0.22), had fewer depressive symptoms (d = 0.08), less wealthy (d = 0.07), and younger (d = 0.04) at their initial assessment.

Participants, during their first assessment, were drawn primarily from Western (44.61%) and Southern Europe (22.74%), but included people from Northern Europe (16.76%), Eastern Europe (9.67%), and Israel (6.22%). They were 64 years old on average (SD = 10.01), ranging in birth year from 1902 to 1969. The majority were women (52.7%), married (65.7%), and Protestant (24.3%) or Catholic (40.6%) in faith.Table 1 displays the characteristics of the participants included in the study.

Measures

Demographic variables. The SHARE study assessed a variety of demographic variables, including age, gender, and household income percentile.

Cognitive functioning. Cognitive functioning was measured in two domains derived from three cognitive tasks: verbal fluency, immediate word recall, and delayed word recall. These three measures indexed the constructs of executive function and memory ability.

Executive function. Executive function was assessed using a category fluency task where participants were asked to name as many animals correctly as possible during a one-minute period. The measure is an assessment of executive functioning, as participants must devise a strategy for recalling category exemplars. It is sensitive to alterations in executive functions in patients with frontal lobe damage (Stuss et al., 1998) and has been used widely as a component of neuropsychological batteries to differentiate between healthy age-related memory change and clinically significant impairments (Haugrud, Crossley, & Vrbancic, 2011)

Memory Function. Memory function was assessed using immediate and delayed word recall from the Ten-Word Delayed Recall Test. Ten common words were presented and participants were asked to recall the words immediately and then again five minutes later. The two scores were averaged to create the measure of memory. This assessment was constructed based on similar computerized word recall tasks that have been used extensively to assess immediate and delayed memory performance (Green, Montijo, & Brockhaus, 2011; Hoskins, Binder, Chaytor, Williamson, & Drane, 2010).

Social Participation. Social participation was measured using a sum score of participants' responses to four questions regarding their participation in categories of social activities that promote social involvement over the past month. The four categories of social activities were how often they had participated in: (1) voluntary or charity work, (2) a sport, social or other kind of club, (3) a religious organization, and (4) a political or community organization. Two additional activity types were not included (caring for a sick or disabled adult; attending an

educational or training course), as they may not reflect voluntary social interactions. Responses were coded as zero for no participation, one for less often than weekly, two for almost every week, and three for participating almost daily. The fourth wave of data collection changed the question from how often in the past month participants had engaged in an activity to the past year. The frequency for each activity included the additional option of "less than every month," however, along with four options that matched the previously used frequencies. To maintain a scale equal to the absolute frequency asked in waves one and two, responses of less than every month were coded as zero for no participation or participation less than monthly on average. Higher scores indicated higher levels of social participation.

Physical health. Physical health was measured using participants' response to a five point likert-scale read out to them asking "Would you say your health is…" with responses ranging from "excellent" to "very poor." Participants were randomized to receive the question either at the beginning or end of the broader physical health questionnaire to account for response biasing. Scores were coded so that higher scores denoted lower self-perceived physical health. In general, self-perceived health is considered a valid measure of physical health among aged adults and is predictive of future health problems and mortality (Idler & Benyamini, 1997).

Depressive symptoms. Depressive symptoms were measured using the EURO-D, a measure designed to assess the self-reported presence of depressive symptoms within the European Union (Castro-Costa et al., 2007; Prince et al., 1999a). The scale uses 12 binary yes-no items (1, 0; e.g. "Have you been sad recently" and "Have you cried recently"). The sum of the items represents self-reported symptoms of depression, with greater scores denoting higher levels of depressive symptoms.

Physical activity. Physical activity was measured using a single-item self-report question assessing participants' frequency of moderate physical activity, "How often do you engage in activities that require a low or moderate level of energy such as gardening, cleaning the car, or going for a walk?" Responses to the four-point scale were coded from one to four for the responses "more than once a week," "once a week," "one to three times a month," and "hardly ever, or never," with higher scores indicating lower frequency of physical activity. We also ran all analyses using vigorous physical activity. All following substantive results replicated in those analyses, though the within-occasion associations of vigorous activity were slightly smaller than moderate activity.

Data Analysis

In the current study, we evaluated the association between social participation and cognitive functioning over time by estimating latent curve growth models (LCGM) for memory and executive function (EF). The full SHARE sample was split into two random subsamples, each containing half of the 19,832 participants. We first evaluated the main hypotheses concerning the time-based association of memory and EF with social participation in an initial random subsample of study participants. We then conducted confirmatory analyses in the second subsample of participants to replicate the results from the initial subsample. The basic LCGM included three time points (T0, T1, and T3), with T2 excluded, as it did not include social or cognitive measures. Using the three time points, we estimated the intercept and slope for memory and executive function. Both models' slope and intercept were estimated freely and permitted to covary. The slope and intercept of cognition were also regressed on age, gender, and income percentile as covariates. To evaluate our questions of interest, the manifest cognitive functioning variables were regressed on social participation and three alternative predictors

(depressive symptoms, self-rated health, and physical activity level). In addition, we included the association of T0 social participation and the three alternative predictors and the slope of the cognitive functioning variables. The conceptual analytic model is presented in Figure 1.

To identify the best-fitting LGCM in the first subsample, we compared nested model specifications using a chi-square difference tests [$\chi^2_{\text{Model 2}} - \chi^2_{\text{Model 1}} (df_{\text{Model 2}} - df_{\text{Model 1}})$]. If constraining parameters did not adversely affect model fit, we retained the more parsimonious model. When using maximum likelihood (ML) estimation, McArdle and Nesselroade (2014) suggested using common fit measures to assess comparative model fit. In the current study, we used the root-mean-squared error of approximation (RMSEA) and comparative fit index (CFI) and considered models to have relatively good fit if RMSEA values < .06 and CFI values > .95.

Once we established the best fitting models in the initial sample, we constrained all elements of the replication models to the estimated parameter estimates in the final initial models. We then explored if removing the constraints for the parameters from the initial sample improved model fit using chi-squared difference tests. Finally, we examined whether the unconstrained replication samples estimates replicated the substantive results of the initial samples.

When examining the strength of associations, we compared the standardized estimates of the within-occasion associations across all four time-varying covariates. These values represent the amount of standard deviation (*SD*) change in the cognitive outcomes predicted by a 1 *SD* change in the predictor. The standardized values are calculated using the formula $\beta = b*SD(x)/SD(y)$ for continuous predictors, and $\beta = b/SD(y)$ for dichotomous variables, (Muthén & Muthén, 2011). We ran all models in MPlus v. 7.2 (Muthén & Muthén, 2011) using full

information maximum likelihood (FIML) estimation for missing data, and simultaneous regression for all path models.

Results

Table 2 displays descriptive statistics for the participants in the current study and Table 3 provides a correlation matrix of all variables included in the study as estimated using FIML. Of note, the average social participation in this sample was relatively low, with 0.97 activities across assessments, equivalent to one activity a month.

Using the initial subsample, we first constructed the unconstrained univariate LCGM for memory function. The initial model fit the data adequately, χ^2 (1, N = 9,905) = 9.32, p = .002, CFI = 1.00, RMSEA = .029. We next constructed the unconstrained univariate LCGM for executive functioning (EF). The initial model for EF also fit the data adequately, χ^2 (1, N = 9,879) = 0.76, p = 3.83, CFI = 1.00, RMSEA = .000. Having established the basic LGCMs, we next included the relevant time-varying covariates (social participation, physical health, physical activity level, and depressive symptoms) predicting the manifest cognition variables at T0, T1, and T3, as well as the time-invariant covariates (age at study start, gender, and income) predicting the slope and intercept of memory and EF in both models. Finally, we included a direct association of social participation, physical health, physical activity level, and depressive symptoms at T0 predicting the slope of the cognitive measures.

Memory Function

The final model for memory function fit the data adequately, χ^2 (24, N = 9,916) = 242.49, p < .001, CFI = 0.98, RMSEA = .030. The slope and intercept of memory covaried significantly, B = -0.08, 95% CI [-1.10, -0.04]. In addition, age significantly predicted the intercept, B = -0.56, [-0.59, -0.52], and slope of memory, B = -0.07, [-0.09, -0.05]. Gender also predicted both the

intercept, B = 0.32, [0.26, 0.38], and slope of memory, B = 0.07, [0.04, 0.10]. Income level predicted the intercept B = 0.06, [0.04, 0.07], but not slope, of memory function.

We next examined the strength of the time-varying covariates – social participation, health, physical activity, and depression – predicting memory functioning across time. Social participation, health, depression, and physical activity all significantly predicted memory function at all three time points. In addition, social participation, health, depression, and physical activity at T0 independently predicted the slope of memory functioning, such that lower social participation, physical health, and physical activity, as well as higher depressive symptoms, uniquely predicted a steeper decline in memory functioning. The full standardized model results are presented in Table 4. Comparisons of the standardized strength of health, depressive symptoms, and social participation's association with memory revealed the competing predictors were relatively comparable, both within occasion and predicting the slope of memory function, with the exception of T3 social participation, which was ½ to ¼ the size of the alternative predictors.

Executive Function

The final model for executive function fit the data adequately, χ^2 (28, N = 9,916) = 220.03, p < .001, CFI = 0.98, RMSEA = .029. The slope and intercept of EF covaried significantly, B = -1.35, 95% CI [-1.94, -0.76]. In addition, age significantly predicted the intercept, B = -1.58, [-1.74, -1.43], and slope of EF, B = -0.15, [-0.23, -0.08]. In contrast, gender predicted slope EF, B = 0.17, [0.06, 0.28], but not intercept of EF, whereas income level predicted the intercept B = 0.24, [0.18, 0.29], but not slope of EF.

We next examined the strength of the time-varying covariates – social participation, health, physical activity, and depression – predicting EF across time. Social participation, health,

depression, and physical activity all significantly predicted executive function at all three time points. In addition, social participation, health, depression, and physical activity at T0 independently predicted the slope of EF, such that lower social participation, physical health, and physical activity, as well as higher depressive symptoms uniquely predicted a steeper decline in EF. The full standardized model results are presented in Table 5. Comparisons of the standardized strength of health, depressive symptoms, and social participation's association with memory revealed the competing predictors were relatively comparable, both within occasion and predicting the slope of memory function, with the exception of T3 physical health, which approximately 4 times the size of the other predictors.

Replication Analyses

To replicate the results observed in the initial subsample, we examined the model presented in Figure 1 in the second confirmatory subsample for both memory and EF. In both models, we first constrained all elements of the model to the first subsample estimates (fully-constrained replication). This model specification provided an adequate fit in the confirmatory subsample for both memory, χ^2 (47, n = 9,916) = 286.75, p < .001, CFI = 0.98, RMSEA = .023, and EF, χ^2 (47, n = 9,916) = 362.76, p < .001, CFI = 0.97, RMSEA = .026. We then removed all constraints on the model estimates. This significantly improved the chi-squared model fit for both memory, χ^2 (23, N = 9,916) = 57.74, p < .001 and executive function, χ^2 (22, N = 9,916) = 123.29, p < .001. The unconstrained models fit the data adequately for both memory, χ^2 (24, N = 9,916) = 229.01, p < .001, CFI = 0.98, RMSEA = .029 and EF, χ^2 (25, N = 9,916) = 239.57, p < .001, CFI = 0.98, RMSEA = .029, though in order to maintain a positive definite PSI matrix, the covariation of the intercept and slope of EF was constrained to equal the initial estimate (-1.35) in the EF unconstrained replication model.

Although the chi-squared difference test was significant in these cases, even small differences in model specification misfit can result in significant chi-squared differences in large samples. The lack of improvement in CFI and relatively higher RMSEA when in the unconstrained models suggest that the results of interest replicate in the second independent subsample, though some estimates of the other model parameters may differ slightly between the two subsamples. Investigation of the unconstrained samples revealed all substantive results replicated in the subsample, except for the association of T3 social participation and T3 executive functioning, which was non-significant (p = .091). Full results of the unconstrained replication subsample results are presented in Tables 3 and 4.

Discussion

This study investigated cognitive functioning, as indexed by memory and executive functioning, in a longitudinal sample of aging adults from 13 European counties and Israel. As hypothesized, after accounting for the effects of self-reported mood symptoms, physical activity, and physical heath, higher levels of social participation were uniquely associated with higher levels of within-occasion memory and executive functioning. In addition, social participation at the study's start predicted change in both memory and executive functioning over time. The relative magnitude of the social participation effect was comparable to the effects of physical health, depressive symptoms, and physical activity. These results replicated in a second random subsample of participants.

A primary strength of this study is the large, representative, multi-national nature of the SHARE data. With large samples, however, comes the statistical power to detect small or even trivial effects as significant. Thus, an important first question is whether the current findings are practically meaningful. One method of calibrating an effect of interest is to use a benchmarking

approach to compare relative effect sizes to other established predictors or correlates of an outcome of interest (Sechrest et al., 1996). One way to understand the magnitude and potential meaning of the social participation effect is to compare it to the effect of participants' age on cognitive functioning. In the first subsample, one standard deviation (*SD*) change in age equaled a difference of 10.06 years and predicted a change of -0.26 and -0.15 of a standard deviation in the slope of memory and executive functioning respectively. In comparison, a one *SD* unit decrease in participants' within-occasion social participation (accounting for mood symptoms, physical activity, and physical health) resulted in a change of 0.21 and 0.19 of a *SD* in the slope of memory and executive functioning. The results suggest that the size of the association of social participation and cognitive functioning is similar to that of age and cognition. Said differently, a 1 *SD* change in social participations is equivalent to around 10 years of average cognitive decline.

Social participation, health, depressive symptoms, and physical activity all uniquely predicted memory and executive function within occasion across the length of the study. In addition, lower social participation, physical health, and physical activity, as well as higher depressive symptoms, at T0 uniquely predicted faster decline in memory and executive functioning. As such, we have evidence to reject the notion that a single common cause among these variables underlies the overall effect on cognition. Although participants reported relatively low rates of social participation (i.e., an average total score of one activity per month), this distribution matches social participation levels, both in studies from the SHARE dataset (Croezen et al, 2015; Sirven & Debrand, 2008), as well as other samples of aging adults (Ellaway & Macintyre, 2007; Glei et al., 2005).

The question remains, however, what potential mechanisms might explain how social participation could cause changes in cognitive functioning? The present study did not explicitly compare the cognitive-reserve/enrichment and stress hypotheses (Fillit et al, 2002), but the unique prediction of cognitive functioning by both social participation and depression suggests that associations between social participation and cognition are not completely mediated by changes in one element of psychological stress, depressive symptoms. In addition, these findings suggest that involvement in social activities may act as a buffer against cognitive decline by increasing aging adults' exposure to cognitively demanding environments, further supporting the cognitive enrichment hypothesis. These two theories present two plausible interpretations for how social participation may affect cognitive functioning. Future studies should specifically compare reported differences in enriched social environments, psychological stress levels, and physiological response profiles among aging adults to determine what mediates this relationship.

It is important to note that these findings reflect epidemiological-level predictive effects that may or may not translate into direct causal mechanisms. McGue and Christensen (2007) reported up to 78% of initial cognitive functioning and 100% of change in functioning is attributable to genetic factors, suggesting that exposure to social activities is not the putatively causal agent driving changes in cognitive functioning. This suggests that high levels of social participation and cognitive functioning share a common genetic variance, perhaps due, for example, to heritable dimensions of personality like extraversion (Krueger et al., 2009; Jang, Livesley, & Vemon, 1996). Alternatively, it is possible that changes in the brain could precede and/or cause changes in social activities (Hultsch, Hertzog, Small, & Dixon, 1999). Despite the fact that social participation was measured retrospectively over the prior month (and thus occurred prior to the cognitive testing, assuming accurate reporting), it may be that changes

occur over a far longer period. For example, studies have found increased brain atrophy (Schott et al., 2003) and beta-amyloid plaque deposition (Price & Morris, 1999), factors implicated in Alzheimer's disease, years before the presentation of cognitive decline. In contrast, there is evidence from intervention studies targeting social engagement (Fried et al., 2004) that suggest assignment to socially-engaging environments result in meaningful gains for aging adults' cognition (Hertzog et al., 2008) and changes in social participation may have meaningful impacts on cognition.

The findings from this study should be considered in light of several limitations. First, although the measures of cognition in the current study are widely used, they lack the depth of more intensive cognitive batteries that could better define specific aspects of cognition affected by social participation. Second, our index of social participation was assessed using self-reported involvement in four specific social activities over the past month. Participants' estimates of their participation in structural elements of social activities are different than other measures of social integration, which may preclude broad generalizations about social behaviors and attitudes and cognitive function outcomes. Third, though the effect of social participation was calibrated against alterative predictors such as health, depression, and physical activity, this calibration did not provide absolute values in terms of change in meaningful outcomes, such as quality of life. Finally, this study did not explicitly test potential mediators of change in cognitive functioning over time. Future studies could compare if stress or environmental enrichment explains variation in trajectories of cognitive decline.

Conclusion

The present study provides further evidence that social participation is associated with memory and executive functioning over time among aging adults. Social participation predicted

cognitive functioning both within-occasion and over time in the multinational SHARE sample, and the results replicated in a second random subsample. Social participation was associated with memory and executive function independent of the effects of self-reported health, depression, and physical activity, and was comparable in magnitude to the association of these competing predictors and cognition. These results suggest that interventions designed to target cognition via increasing social participation have promise and may be as effective or more effective than treatments targeting other predictors of cognitive decline, such as depression, health, and physical activity level. In short, social participation predicted cognitive functioning over time, the size of this effect compared favorably with alternative established predictors, and the effects were practically meaningful when compared with the average effects of aging.

References

Adam, E. K., Hawkley, L. C., Kudielka, B. M., & Cacioppo, J. T. (2006). Day-to-day dynamics of experience–cortisol associations in a population-based sample of older adults. *Proceedings of the National Academy of Sciences*, *103*(45), 17058-17063. doi: 10.1073/pnas.0605053103

Beekman, A. T., Penninx, B. W., Deeg, D. J., Ormel, J., Braam, A. W., & van Tilburg, W. (1997). Depression and physical health in later life: results from the Longitudinal Aging Study Amsterdam (LASA). *Journal of Affective Disorders*, *46*(3), 219–231. doi:10.1016/S0165-0327(97)00145-6

Berkman, L. F., & Glass, T. (2000). Social integration, social networks, social support, and health. Berkman, L. F., & Kawachi, I. (Eds.). *Social epidemiology*. Oxford: Oxford University Press.

Börsch-Supan, A., Brandt, M., Hunkler, C., Kneip, T., Korbmacher, J., Malter, F., … Zuber, S. (2013). Data Resource Profile: the Survey of Health, Ageing and Retirement in Europe (SHARE). *International Journal of Epidemiology*, *42*(4), 992–1001. doi:10.1093/ije/dyt088

Brown, C. L., Gibbons, L. E., Kennison, R. F., Robitaille, A., Lindwall, M., Mitchell, M. B., … Piccinin, A. M. (2012). Social activity and cognitive functioning over time: a coordinated analysis of four longitudinal studies. *Journal of Aging Research*, *2012*, 1–12. doi:10.1155/2012/287438

Cacioppo, J. T., & Hawkley, L. C. (2009). Perceived social isolation and cognition. *Trends in Cognitive Sciences*, *13*(10), 447-454. doi:10.1016/j.tics.2009.06.005

Carstensen, L. (1999). Taking time seriously: A theory of socioemotional selectivity. *American Psychologist*, *54*(3), 165–181. Doi:10.1111/j.1540-5907.2007.00307.x

Castro-Costa, E., Dewey, M., Stewart, R., Banerjee, S., Huppert, F., Mendonca-Lima, C., … Prince, M. (2007). Prevalence of depressive symptoms and syndromes in later life in ten European countries: the SHARE study. *The British Journal of Psychiatry*, *191*, 393–401. doi:10.1192/bjp.bp.107.036772

Churchill, J. D., Galvez, R., Colcombe, S., Swain, R. A, Kramer, A. F., & Greenough, W. T. (2002). Exercise, experience and the aging brain. *Neurobiology of Aging*, *23*(5), 941–955. doi: 10.1016/S0197-4580(02)00028-3

Depp, C. A, & Jeste, D. V. (2006). Definitions and predictors of successful aging: a comprehensive review of larger quantitative studies. *The American Journal of Geriatric Psychiatry*, *14*(1), 6–20. doi:10.1097/01.JGP.0000192501.03069.bc

Ellaway, A., & Macintyre, S. (2007). Is social participation associated with cardiovascular disease risk factors?. *Social Science & Medicine*, *64*(7), 1384-1391. doi:10.1016/j.socscimed.2006.11.022

Fried, L. P., Carlson, M. C., Freedman, M., Frick, K. D., Glass, T. A., Hill, J., ... & Zeger, S. (2004). A social model for health promotion for an aging population: initial evidence on the Experience Corps model. *Journal of Urban Health*, *81*(1), 64-78. doi:10.1093/jurban/jth094

Fillit, H. M., Butler, R. N., O'Connell, A. W., Albert, M. S., Birren, J. E., Cotman, C. W., ... & Tully, T. (2002). Achieving and maintaining cognitive vitality with aging. In *Mayo Clinic Proceedings*, *77*(7), 681-696. doi: 10.4065/77.7.681

Fratiglioni, L., Paillard-Borg, S., & Winblad, B. (2004). An active and socially integrated lifestyle in late life might protect against dementia. *The Lancet Neurology*, *3*, 343–353. doi:10.1016/S1474-4422(04)00767-7

Geerlings, S. W., Beekman, A. T., Deeg, D. J., & Van Tilburg, W. (2000). Physical health and the onset and persistence of depression in older adults: an eight-wave prospective community-based study. *Psychological Medicine*, *30*(2), 369–380. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10824657

Glass, T. A., De Leon, C. F. M., Bassuk, S. S., & Berkman, L. F. (2006). Social engagement and depressive symptoms in late life longitudinal findings. *Journal of Aging and Health*, *18*(4), 604-628.

Glei, D. A, Landau, D. A, Goldman, N., Chuang, Y. L., Rodríguez, G., & Weinstein, M. (2005). Participating in social activities helps preserve cognitive function: an analysis of a longitudinal, population-based study of the elderly. *International Journal of Epidemiology*, *34*(4), 864–71. doi:10.1093/ije/dyi049

Green, A., Rebok, G., & Lyketsos, C. (2008). Influence of social network characteristics on cognition and functional status with aging. *International Journal of Geriatric Psychiatry*, *23*(9), 972–978. doi:10.1002/gps.2023.Influence

Green, P., Montijo, J., & Brockhaus, R. (2011). High specificity of the Word Memory Test and Medical Symptom Validity Test in groups with severe verbal memory impairment. *Applied Neuropsychology*, *18*(2), 86–94. doi:10.1080/09084282.2010.523389

Harkness J. (2005). SHARE translation procedures and translation assessment. In Börsch-Supan A, Jürges H, (Eds.), *The Survey of Health, Aging and Retirement in Europe: Methodology* (pp. 24-27). Mannheim, Germany: Mannheim Research Institute for the Economics of Aging.

Haugrud, N., Crossley, M., & Vrbancic, M. (2011). Clustering and switching strategies during verbal fluency performance differentiate Alzheimer's disease and healthy aging. *Journal of*

the International Neuropsychological Society : JINS, *17*(6), 1153–7. doi:10.1017/S1355617711001196

Hertzog, C., Kramer, A. F., Wilson, R. S., & Lindenberger, U. (2008). Enrichment effects on adult cognitive development can the functional capacity of older adults be preserved and enhanced?. *Psychological Science in the Public Interest*, *9*(1), 1-65. doi:10.1111/j.1539-6053.2009.01034.x

Heyn, P., Abreu, B. C., & Ottenbacher, K. J. (2004). The effects of exercise training on elderly persons with cognitive impairment and dementia: A meta-analysis. *Archives of Physical Medicine and Rehabilitation*, *85*(10), 1694–1704. doi:10.1016/j.apmr.2004.03.019

Hoskins, L. L., Binder, L. M., Chaytor, N. S., Williamson, D. J., & Drane, D. L. (2010). Comparison of oral and computerized versions of the word memory test. *Archives of Clinical Neuropsychology : The Official Journal of the National Academy of Neuropsychologists*, *25*(7), 591–600. doi:10.1093/arclin/acq060

Hultsch, D. F., Hertzog, C., Small, B. J., & Dixon, R. A. (1999). Use it or lose it: engaged lifestyle as a buffer of cognitive decline in aging?. *Psychology and aging*, *14*(2), 245-263. doi: 10.1037/0882-7974.14.2.245

Idler, E. L., & Benyamini, Y. (1997). Self-rated health and mortality: a review of twenty-seven community studies. *Journal of Health and Social Behavior*, *38*(1), 21–37. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9097506

James, B. D., Wilson, R. S., Barnes, L. L., & Bennett, D. A. (2011). Late-life social activity and cognitive decline in old age. *Journal of the International Neuropsychological Society*, *17*(6), 998–1005. doi:10.1017/S1355617711000531

Jang, K. L., Livesley, W. J., & Vemon, P. A. (1996). Heritability of the big five personality dimensions and their facets: a twin study. *Journal of Personality*, *64*(3), 577-592. doi: 10.1111/1467-6494.ep9703132895

Krueger, K. R., Wilson, R. S., Kamenetsky, J. M., Barnes, L. L., Bienias, J. L., & Bennett, D. A. (2009). Social engagement and cognitive function in old age. *Experimental Aging Research*, *35*, 45–60. doi:10.1080/03610730802545028

Lindström, M., Moghaddassi, M., & Merlo, J. (2004). Individual self-reported health, social participation and neighbourhood: a multilevel analysis in Malmö, Sweden. *Preventive Medicine*, *39*(1), 135-141. doi: 10.1016/j.ypmed.2004.01.011

Lupien, S. J., McEwen, B. S., Gunnar, M. R., & Heim, C. (2009). Effects of stress throughout the lifespan on the brain, behaviour and cognition. *Nature Reviews Neuroscience*, *10*(6), 434-445. doi:10.1038/nrn2639

McArdle, J.J & Nesselroade, J.R. (2014). Longitudinal Data Analysis Using Structural Equation Models. Washington, DC: APA Books.

McGue, M., & Christensen, K. (2007). Social activity and healthy aging: a study of aging Danish twins. *Twin Research and Human Genetics : The Official Journal of the International Society for Twin Studies*, *10*(2), 255–265. doi:10.1375/twin.10.2.255

Muthén, L.K. and Muthén, B.O. (1998-2012). Mplus User's Guide. Seventh Edition. Los Angeles, CA: Muthén & Muthén

Ownby, R. L., Crocco, E., Acevedo, A., John, V., & Loewenstein, D. (2006). Depression and risk for Alzheimer disease: systematic review, meta-analysis, and metaregression analysis. *Archives of General Psychiatry*, *63*(5), 530-538. doi:10.1001/archpsyc.63.5.530

Park, H. L., O'Connell, J. E., & Thomson, R. G. (2003). A systematic review of cognitive decline in the general elderly population. *International Journal of Geriatric Psychiatry, 18*(12), 1121–1134. doi:10.1002/gps.1023

Perlmutter, M., & Nyquist, L. (1990). Relationships between self-reported physical and mental health and intelligence performance across adulthood. *Journal of Gerontology, 45*(4), 145–155. doi:10.1093/geronj/45.4.P145

Price, J. L., & Morris, J. C. (1999). Tangles and plaques in nondemented aging and" preclinical" Alzheimer's disease. *Annals of neurology, 45*(3), 358-368. doi: 10.1002/1531

Prince, M., Acosta, D., Chiu, H., Scazufca, M., & Varghese, M. (2003). Dementia diagnosis in developing countries: a cross-cultural validation study. *Lancet, 361*(9361), 909–917. doi:10.1016/S0140-6736(03)12772-9

Prince, M. J., Beekman, A. T., Deeg, D. J., Fuhrer, R., Kivela, S. L., Lawlor, B. A., … Copeland, J. R. (1999). Depression symptoms in late life assessed using the EURO-D scale. Effect of age, gender and marital status in 14 European centres. *The British Journal of Psychiatry, 174*(4), 339–345. doi:10.1192/bjp.174.4.339

Restrepo, H., & Rozental, M. (1994). The social impact of aging populations: Some major issues. *Social Science & Medicine, 39*(9), 1323–1338. doi:10.1016/0277-9536(94)90364-6

Rowe, J., & Kahn, R. (1997). Successful aging. *The Gerontologist, 37*(4), 433–440. doi:10.1093/geront/37.4.433

Salthouse, T. A. (Ed.). (1991). *Theoretical perspectives on cognitive aging*. New Jersey: Psychology Press.

Schott, J. M., Fox, N. C., Frost, C., Scahill, R. I., Janssen, J. C., Chan, D., ... & Rossor, M. N. (2003). Assessing the onset of structural change in familial Alzheimer's disease. *Annals of neurology*, *53*(2), 181-188. doi: 10.1002/ana.10424

Sechrest, L., McKnight, P., & McKnight, K. (1996). Calibration of measures for psychotherapy outcome studies. *American Psychologist*, *51*(10), 1065-1071. doi:10.1037/0003-066X.51.10.1065

Seeman, T. E., Miller-Martinez, D. M., Merkin, S. S., Lachman, M. E., Tun, P. A., & Karlamangla, A. S. (2010). Histories of social engagement and adult cognition: Midlife in the US Study. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences,* 141-152. doi: 10.1093/geronb/gbq091

Sofi, F., Valecchi, D., Bacci, D., Abbate, R., Gensini, G. F., Casini, A., & Macchi, C. (2011). Physical activity and risk of cognitive decline: a meta-analysis of prospective studies. *Journal of Internal Medicine, 269*(1), 107–117. doi:10.1111/j.1365-2796.2010.02281.x

Sirven, N., & Debrand, T. (2008). Social participation and healthy ageing: An international comparison using SHARE data. *Social Science & Medicine, 67*(12), 2017-2026. doi:10.1016/j.socscimed.2008.09.056

Tombaugh, T. N., Kozak, J., & Rees, L. (1999). Normative data stratified by age and education for two measures of verbal fluency: FAS and animal naming. *Archives of Clinical Neuropsychology*, *14*(2), 167–177. doi:10.1016/S0887-6177(97)00095-4

Uchino, B. N. (2004). *Social support and physical health: Understanding the health consequences of relationships*. New Haven, CT: Yale University Press.

Zelinski, E., Crimmins, E., Reynolds, S., & Seeman, T. (1998). Do medical conditions affect cognition in older adults? *Health Psychology, 17*(6), 504–512. doi:10.1037/0278-6133.17.6.504

Zunzunegui, M. V., Alvarado, B. E., Del Ser, T., & Otero, A. (2003). Social networks, social integration, and social engagement determine cognitive decline in community-dwelling Spanish older adults. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences*, *58*(2), 93–100. doi:10.1093/geronb/58.2.S93

Table 1
Sample Characteristics

N = 19,832		
Geographic area		
	Northern Europe	16.76%
	Southern Europe	22.74%
	Western Europe	44.61%
	Eastern Europe	9.67%
	Israel	6.22%
Language		
	Czech	4.5%
	Danish	7.4%
	Dutch	8.4%
	Flemish	6.5%
	French	10.6%
	German	15.0%
	Greek	7.9%
	Hebrew	5.2%
	Italian	8.3%
	Polish	5.2%
	Spanish	6.7%
	Swedish	9.3%
Religious Affiliation		
	Protestant	24.3%
	Catholic	40.6%
	Orthodox	11.4%
	Jewish	7.3%
	Muslim	1.0%
	None	2.1%
	Other	13.2%
Marital Status		
	Married	65.7%
	Never Married	6.4%
	Divorced	8.8%
	Widowed	19.1%
Year of Birth	1940 ± 10.17	
Years of Education	10.58 ± 4.39	
Household Size	2.18 ± 1.16	
Number of Children	2.25 ± 1.53	

Data are means ± standard deviations. All means and SDs were calculated using FIML. Regions were defined as; Northern Europe (Denmark and Sweden); Southern Europe (Greece, Italy, and Spain); Western Europe (Austria, Belgium, France, Germany, Netherlands, and Switzerland); Eastern Europe (Czechoslovakia and Poland). Only languages with percentages above 1% were included, and dialects were included under the main language category.

Table 2

Descriptive Statistics for Variables of Interest for Full Sample

N = 19,832	T0	T1	T3
Executive Function	19.16 ± 0.77	18.95 ± 0.81	18.33 ± 0.91
Memory Function	4.08 ± 0.77	4.18 ± 0.81	4.20 ± 0.91
Social Participation	0.93 ± 1.48	0.92 ± 1.48	1.06 ± 1.55
Physical Health	2.91 ± 1.07	3.10 ± 1.09	3.22 ± 1.09
Depression	2.39 ± 2.24	2.34 ± 2.27	2.53 ± 2.28
Moderate Physical Activity	1.55 ± 1.33	1.63 ± 1.34	1.75 ± 1.34
Age	64.42 ± 10.01		
Income Percentile	5.32 ± 2.55		
Gender	53.7% women		

Data are means ± standard deviations. Income percentile ranges from 1 to 10. All means and SDs were calculated using full information maximum likelihood (FIML).

Table 3

Correlation Matrix for Variables of Interest

	Complete Sample																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Mem T0 (1)	-																				
Mem T1 (2)	.62	-																			
Mem T3 (3)	.56	.60	-																		
EF T0 (4)	.48	.46	.47	-																	
EF T1 (5)	.45	.52	.50	.64	-																
EF T3 (6)	.44	.47	.56	.61	.62	-															
Soc T0 (7)	.15	.18	.18	.19	.17	.16	-														
Soc T1 (8)	.16	.20	.20	.21	.22	.18	.55	-													
Soc T3 (9)	.15	.18	.22	.17	.19	.20	.47	.52	-												
Hea T0 (10)	-.30	-.28	-.28	-.30	-.29	-.29	-.16	-.18	-.18	-											
Hea T1 (11)	-.29	-.31	-.30	-.28	-.30	-.30	-.14	-.20	-.20	.59	-										
Hea T3 (12)	-.29	-.30	-.35	-.28	-.27	-.32	-.15	-.17	-.24	.56	.59	-									
Dep T0 (13)	-.22	-.21	-.22	-20	-.20	-.21	-.11	-.11	-10.	.40	.34	.31	-								
Dep T1 (14)	-.20	-.25	-.23	-.18	-.22	-.21	-.10	-.13	-.12	.36	.44	.34	.56	-							
Dep T3 (15)	-.18	-.21	-.27	-.20	-.20	-.26	-.10	-.12	-.15	.34	.36	.45	.50	.51	-						
P. Act T0 (16)	-.21	-.24	-.26	-.22	-.29	-.29	-.13	-.13	-.13	.29	.25	.25	.24	.22	.21	-					
P. Act T1 (17)	-.20	-.26	-.27	-.23	-.30	-.30	-.12	-.18	-.16	.29	.33	.27	.22	.30	.24	.47	-				
P. Act T3 (18)	-.21	-.25	-.33	-.24	-.27	-.32	-.11	-.14	-.21	.31	.32	.37	.22	.26	.31	.38	.42	-			
Age (19)	-.40	-.43	-.50	-.29	-.32	-.41	-.04	-.08	-.15	.25	.27	.30	.11	.16	.20	.17	.25	.34	-		
Income (20)	.26	.25	.29	.23	.24	.27	.07	.08	.09	-.22	-.22	-.23	-.14	-.15	-.16	-.10	-.13	-.16	-.36	-	
Gender (21)	-.03	-.05	-.05	-.07	-.05	-.04	-.05	-.04	-.00	.08	.07	.06	.23	.19	.18	.06	.07	.07	.04	-.15	-

Mem = Memory function, EF = executive function, Soc = social participation, Hea = physical health, Dep = depressive symptoms, P. Act = moderate physical activity level, Income = income percentile out of 10. All correlations were calculated using full information maximum likelihood (FIML).

Table 4

Parameter Estimates for Latent Curve Parameters, Model Fit, and Regression Coefficients Predicting Memory Function in the Initial and Replication Subsamples

Initial Subsample			
Parameter		Mean	Variance
Memory Intercept		4.84**	1.24**
Memory Slope		0.004	0.26**
Fit Statistics			
H1 log-likelihood		-22606.25	
No. of parameters		24	
χ^2		24.486	
RMSEA		0.030	
CFI		0.98	
Intercept of Memory	*B*	95% CI	β
Age	-0.56**	[-0.59 , -0.52]	-0.45**
Gender	0.32**	[0.26 , 0.38]	0.13**
Income	0.06**	[0.04 , 0.10]	0.13**
With Slope of Cognition	-0.08**	[-0.11 , -0.04]	-0.33**
Slope of Memory	*B*	95% CI	β
Age	-0.07**	[-0.09 , -0.05]	-0.26**
Gender	0.07**	[0.04 , 0.10]	0.14*
Income	0.00	[-0.00 , 0.01]	0.03
Social Participation at T0	0.04**	[0.04 , 0.10]	0.21**
Physical Health at T0	-0.05**	[-0.06 , -0.03]	-0.19**
Depression at T0	-0.02**	[-0.03 , -0.01]	-0.18**
Physical Activity at T0	-0.04**	[-0.06 , -0.02]	-0.15**
Memory at T0	*B*	95% CI	β
Social Participation at T0	0.11**	[0.09 , 0.13]	0.10**
Physical Health at T0	-0.17**	[-0.20 , -0.14]	-0.11**
Depression at T0	-0.08**	[-0.10 , -0.07]	-0.11**
Physical Activity at T0	-0.11**	[-0.15 , -0.08]	-0.07**
Memory at T1	*B*	95% CI	β
Social Participation at T1	0.08**	[0.06 , 0.10]	0.07**
Physical Health at T1	-0.13**	[-0.16 , -0.11]	-0.08**
Depression at T1	-0.07**	[-0.08 , -0.06]	-0.09**
Physical Activity at T1	-0.10**	[-0.12 , -0.07]	-0.06**
Memory at T3	B	95% CI	β
Social Participation at T3	0.03*	[0.01 , 0.06]	0.03*
Physical Health at T3	-0.10**	[-0.14 , -0.05]	-0.05**
Depression at T3	-0.04**	[-0.07 , -0.02]	-0.05**
Physical Activity at T3	-0.13**	[-0.17 , -0.09]	-0.07**
Replication Subsample			
Parameter		Mean	Variance
Memory Intercept		4.76**	1.25**

Memory Slope	-0.01	0.24**
Fit Statistics		
H1 log-likelihood	-226087.01	
No. of parameters	24	
χ^2	229.01	
RMSEA	0.029	
CFI	0.98	

Intercept of Memory	*B*	95% CI	β
Age	-0.50**	[-0.53 , -0.46]	-0.40**
Gender	0.39**	[0.32 , 0.45]	0.15**
Income	0.07**	[0.06 , 0.08]	0.17**
With Slope of Memory	-0.06**	[-0.10 , -0.02]	-0.28**
Slope of Memory	*B*	95% CI	β
Age	-0.08**	[-0.10 , -0.06]	-0.34*
Gender	0.03*	[0.00 , 0.06]	0.07*
Income	-0.00	[-0.01 , 0.00]	-0.02
Social Participation at T0	0.04**	[0.03 , 0.05]	0.27**
Physical Health at T0	-0.05**	[-0.07 , -0.02]	-0.22**
Depression at T0	-0.01**	[-0.02 , -0.01]	-0.13**
Physical Activity at T0	-0.05**	[-0.06 , -0.02]	-0.17**
Memory at T0	*B*	95% CI	β
Social Participation at T0	0.10**	[0.08 , 0.12]	0.09**
Physical Health at T0	-0.13**	[-0.16 , -0.10]	-0.08**
Depression at T0	-0.10**	[-0.11 , -0.08]	-0.09**
Physical Activity at T0	-0.12**	[-0.15 , -0.09]	-0.07**
Memory at T1	*B*	95% CI	β
Social Participation at T1	0.07**	[0.03 , 0.08]	0.08**
Physical Health at T1	-0.11**	[-0.13 , -0.08]	-0.07**
Depression at T1	-0.07**	[-0.13 , -0.06]	-0.09**
Physical Activity at T1	-0.10**	[-0.13 , -0.08]	-0.06**
Memory at T3	*B*	95% CI	β
Social Participation at T3	0.06**	[0.03 , 0.08]	0.04**
Physical Health at T3	-0.09**	[-0.13 , -0.04]	-0.05**
Depression at T3	-0.04**	[-0.09 , -0.04]	-0.07**
Physical Activity at T3	-0.09**	[-0.13 , -0.05]	-0.05**

Note: * $p < .05$; ** $p < .01$. Income percentile ranges from 1 to 10. Confirmatory sample values were calculated based on the unconstrained confirmatory sample model. "With" defines a covariation rather than regressive association.

Table 5

Parameter Estimates for Latent Curve Parameters, Model Fit, and Regression Coefficients Predicting Executive Function (EF) in the Initial and Replication Subsamples

Initial Subsample			
Parameter		Mean	Variance
EF Intercept		22.72**	5.42**
EF Slope		-0.79**	1.04**
Fit Statistics			
H1 log-likelihood		-258994.93	
No. of parameters		24	
χ^2		220.03	
RMSEA		0.029	
CFI		0.98	
Intercept of EF	*B*	95% CI	β
Age	-1.79**	[-1.74 , -1.43]	-0.30**
Gender	-0.01	[-0.28 , 0.26]	-0.00
Income	0.24**	[0.18 , 0.29]	0.13**
With Slope of EF	-1.35**	[-1.94 , -0.76]	-0.31**
Slope of EF	*B*	95% CI	β
Age	-0.15**	[-0.23 , -0.08]	-0.15**
Gender	0.17*	[0.06 , 0.28]	0.08*
Income	0.01	[-0.01 , 0.03]	0.03
Social Participation at T0	0.13**	[0.09 , 0.18]	0.19**
Physical Health at T0	-0.24**	[-0.31 , -0.17]	-0.25**
Depression at T0	-0.08**	[-0.12 , -0.05]	-0.18**
Physical Activity at T0	-0.14**	[-0.21 , -0.07]	-0.13**
EF at T0	*B*	95% CI	β
Social Participation at T0	0.58**	[0.49 , 0.68]	0.09**
Physical Health at T0	-0.91**	[-1.05 , -0.77]	-0.13**
Depression at T0	-0.23**	[-0.30 , -0.16]	-0.07**
Physical Activity at T0	-0.64**	[-0.78 , -0.49]	-0.09**
EF at T1	*B*	95% CI	β
Social Participation at T1	0.41**	[0.33 , 0.48]	0.08**
Physical Health at T1	-0.63**	[-0.73 , -0.52]	-0.09**
Depression at T1	-0.17**	[-0.23 , -0.12]	-0.05**
Physical Activity at T1	-0.61**	[-0.73 , -0.49]	-0.09**
EF at T3	*B*	95% CI	β
Social Participation at T3	0.12*	[0.02 , 0.22]	0.03*
Physical Health at T3	-0.20*	[-0.36 , -0.03]	-0.03*
Depression at T3	-0.12**	[-0.23 , -0.04]	-0.04**
Physical Activity at T3	-0.66**	[-0.81 , -0.51]	-0.10**
Replication Subsample			
Parameter		Mean	Variance
EF Intercept		22.28**	5.34**

EF Slope	-0.56**		0.65
Fit Statistics			
H1 log-likelihood	-258540.40		
No. of parameters	25		
χ^2	239.57		
RMSEA	0.029		
CFI	0.98		
Intercept of EF	*B*	95% CI	β
Age	-1.25**	[-1.45 , -1.09]	-0.23**
Gender	-0.24	[-0.52 , 0.03]	-0.02
Income	0.30**	[0.23 , 0.35]	0.16**
With Slope of EF	-1.35(=)		-0.48**
Slope of EF	*B*	95% CI	β
Age	-0.31**	[-0.38 , -0.24]	-0.36**
Gender	0.27**	[0.15 , 0.39]	0.15**
Income	-0.01	[-0.03 , 0.02]	-0.02
Social Participation at T0	0.19**	[0.14 , 0.23]	0.32**
Physical Health at T0	-0.20**	[-0.28 , -0.13]	-0.25**
Depression at T0	-0.06**	[-0.10 , -0.03]	-0.16**
Physical Activity at T0	-0.22**	[-0.29 , -0.15]	-0.25**
EF at T0	*B*	95% CI	β
Social Participation at T0	0.55**	[0.45 , 0.64]	0.11**
Physical Health at T0	-0.86**	[-1.00 , -0.72]	-0.13**
Depression at T0	-0.18**	[-0.25 , -0.11]	-0.06**
Physical Activity at T0	-0.63**	[-0.82 , -0.48]	-0.09**
EF at T1	*B*	95% CI	β
Social Participation at T1	0.44**	[0.36 , 0.52]	0.09**
Physical Health at T1	-0.53**	[-0.63 , -0.42]	-0.08**
Depression at T1	-0.18**	[-0.24 , -0.13]	-0.06**
Physical Activity at T1	-0.63**	[-0.79 , -0.51]	-0.09**
EF at T3	*B*	95% CI	β
Social Participation at T3	0.09	[-0.01 , 0.20]	0.02
Physical Health at T3	-0.09	[-0.26 , 0.08]	-0.01
Depression at T3	-0.18**	[-0.26 , -0.10]	-0.05**
Physical Activity at T3	-0.46**	[-0.66 , -0.30]	-0.07**

Note: * $p < .05$; ** $p < .01$. Income percentile ranges from 1 to 10. Confirmatory sample values were calculated based on the unconstrained confirmatory sample model, including a constraint of the covariance between the slope and intercept of EF (denoted by =). "With" defines a covariation rather than regressive association.

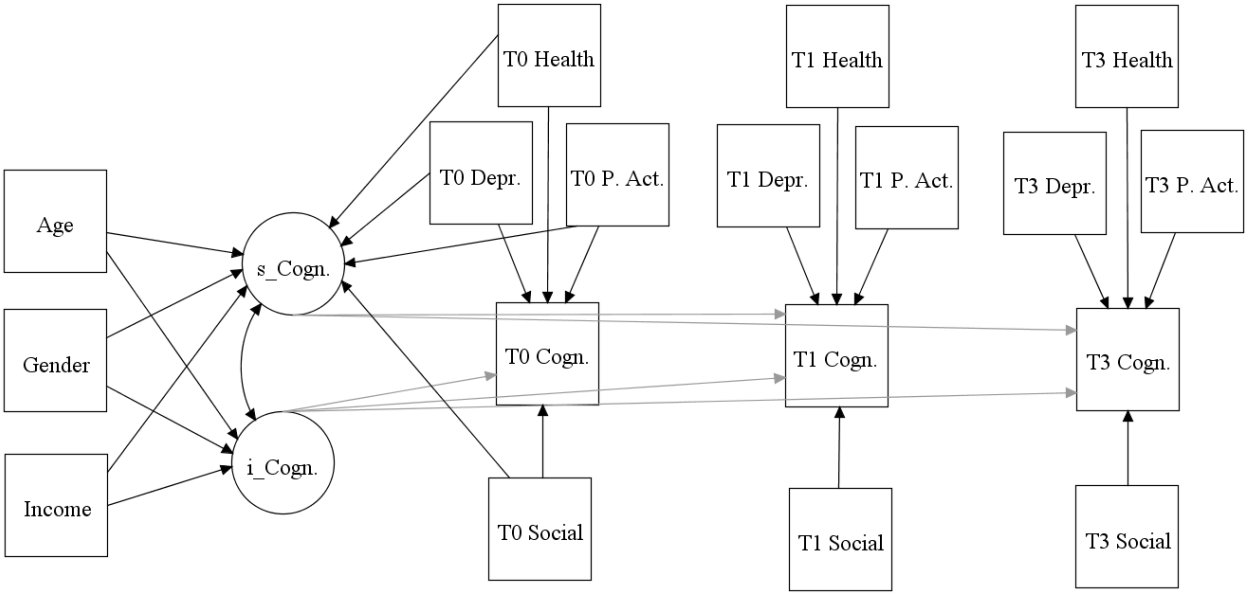

Figure 1. Conceptual model of social participation predicting cognitive functioning over time among aging adults. The model was identical for memory and executive functioning and included time varying and invariant covariates regressed on the manifest variables of cognition and latent curve parameters of cognition respectively to provide comparative sizes of effects on cognition. The parameter estimates for calculating the slope of cognition were constrained to 0, 1, and 3 respectively for T0, T1, and T3. Endogenous variables' residual variances are not illustrated, but were included in the final model. All pathways represent the standardized model values. Cogn. = cognition, depr. = depression, P. Act. = moderate physical activity level, s_ and i_ = the slope and intercept of the construct described.