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Longitudinal associations of volunteering, grandparenting and family care with processing speed – a gender perspective on prosocial activity and cognitive ageing in the second half of life

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Transparency and Openness. The study was not pre-registered. Data from completed waves of the German Ageing Survey are available for the scientific community free of charge. For reasons of data protection, signing a data distribution contract is required before data can be obtained (see https://www.dza.de/en/research/fdz/german-ageing-survey/access-to-deas-data). The syntax for data preparation in SPSS, as well as for all models on Mplus can be found on the OSF server: https://osf.io/7mdk3/ (Henning, 2023). A documentation of all scales and tests of the German Ageing Survey can be accessed here:
https://www.dza.de/en/research/fdz/german-ageing-survey/deas-documentation

Dissemination. Analyses from this paper have been presented in the research colloquium of the Developmental Psychology research group at University of Leipzig, in the colloquium of the Ageing Network at Tilburg University, and as a popular science presentation at the Long Night of Science ("Lange Nacht der Wissenschaften") in Berlin.

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Abstract

An active lifestyle has been associated with better cognitive performance in many studies. However, most studies have focused on leisure activities or paid work, with less consideration of the kind of prosocial activities many people engage in, including volunteering, grandparenting and family care. In the present study, based on four waves of the German Ageing Survey (N = 6,915, aged 40-85 at baseline), we used parallel growth curves to investigate the longitudinal association of level and change in volunteering, grandparenting and family care with level and change in processing speed. Given the gendered nature of engagement in these activities over the lifespan, we tested for gender differences in the associations. Only volunteering was reliably associated with higher speed of processing at baseline, no consistent longitudinal associations were found. Our results show that although prosocial activities are of great societal importance, expectations of large rewards in terms of cognitive health may be exaggerated.

Keywords: Cognitive Aging; Volunteering; Grandparenting; Family Care

Public Significance Statement: Men and women differ in their rate of volunteering, grandparenting and family care, as well as their cognitive ageing when operationalized as processing speed. Those who volunteer in midlife show better cognitive performance, but the direction of effects is not clear.

Introduction

Identifying lifestyle and activity factors as potentially modifiable protective factors for cognitive health is particularly important as there are few medical options to reduce cognitive ageing. Older adults engage in various prosocial behaviours (Allen et al., 2017; Bailey, Ebner, & Stine-Morrow, 2021), including formal volunteering, grandparenting or providing care for partners, parents or other family members (hereafter: 'family care'). In the last decade, researchers have become increasingly interested in the effects of such activities on the cognitive health of the engaged individual (Guiney & Machado, 2017; Zwar, König, & Hajek, 2018).

Previous studies showed positive associations between cognitive health and prosocial activity, but as many studies are cross-sectional, the potential for reverse causality cannot be ignored (Bielak & Gow, 2022). That is, the ability to help others requires physical, cognitive and emotional capacity (Bjälkebring et al., 2021; Kail & Carr, 2020); any association between prosocial activities and functional capacity might be an artefact of function 'allowing' prosocial activities to be done, rather than prosocial activity predicting function.

In the present study, we address these issues by investigating the longitudinal, bidirectional associations of participation in three different types of prosocial activity (i.e., volunteering, grandparenting and family caregiving) with processing speed in a German population-based sample. We further take the role of gender into account.

Activity and Cognitive Ageing

Different cognitive abilities decline at different stages and rates in older age, and in addition, individuals differ in those rates of decline (de Frias, Lövdén, Lindenberger, & Nilsson, 2007; Tucker-Drob, 2019; Tucker-Drob et al., 2022). An active lifestyle is associated with improved cognitive abilities in older age, and has also been shown to be associated with slower declines in cognitive ability (Bielak, Anstey, Christensen, & Windsor, 2012; Gow, Avlund, &

Mortensen, 2014; Gow, Pattie, & Deary, 2017; Luo, Pan, & Zhang, 2019). There are both shared and independent pathways of the potential beneficial effects of activities: First, physical activity may improve cardiovascular functioning and neural structures underlying brain health and cognitive functioning (Bherer, Erickson, & Liu-Ambrose, 2013; Haeger, Costa, Schulz, & Reetz, 2019). Second, in line with the "use it or lose it" concept, social and intellectual activity may help to preserve cognitive abilities by utilizing them in daily life (Bielak, 2010; Bielak & Gow, 2022). Furthermore, an active lifestyle may protect against depressive symptoms, which may also predict subsequent cognitive declines (Bielak, Gerstorf, Kiely, Anstey, & Luszcz, 2011; Dafsari & Jessen, 2020). Despite studies showing cross-sectional and longitudinal associations of activity and cognitive performance, there remains uncertainty about which kind of activities support which cognitive abilities (Bielak, Gerstorf, Anstey, & Luszcz, 2014; Bielak & Gow, 2022; Ghisletta, Bickel, & Lövdén, 2006; Robertson et al., 2023). Furthermore, it is often unclear whether reverse causation is present, which means, that a given level of cognitive ability is a prerequisite for becoming or staying active in specific domains, instead of activity benefitting cognition (Gow, Corley, Starr, & Deary, 2012; X. Li et al., 2022).

Prosocial Activities and cognitive health

Previous studies provided evidence that aspects of an overall active lifestyle such as leisure activities (Iizuka et al., 2019) and mental work demands (Andel, Finkel, & Pedersen, 2015; Finkel, Andel, Gatz, & Pedersen, 2009; Hülür, Ram, Willis, Schaie, & Gerstorf, 2019) are associated with more favourable trajectories of cognitive performance in older age. An active lifestyle in older age may also include prosocial behaviours such as volunteering, grandparenting or family caregiving (Luo et al., 2019). These behaviours are frequent in the older population: In a nationally representative German survey in 2019, 31.2% of the population aged 65 and older reported volunteering formally or informally to some degree (Simonson, Kelle, Kausmann, & Tesch-Römer, 2022a). Furthermore, the highest prevalence of both grandparenting (~24%) and support/family caregiving over the life course (~16%) in Germany was found between midlife and early old age (Klaus & Vogel, 2019).

In recent years, researchers have increasingly studied the role of such prosocial activities for individual cognitive health (Allen et al., 2017; Anderson et al., 2014; Guiney & Machado, 2017). Like leisure activities, these activities may promote increased physical activity, as well as social and mental stimulation, which in turn may increase neurological and mental health and thereby cognitive health (Guiney & Machado, 2017). Prosocial activities are also often associated with higher well-being and positive emotions, especially in older age (Bjälkebring, Västfjäll, Dickert, & Slovic, 2016), which may also support cognitive functioning.

Nevertheless, there are some important differences between leisure activity and the forms of prosocial behaviour investigated in the present study, which may lead to differences in the effects of different activities on cognitive ageing. First, the focus of all three activities is on caring for others, and not for oneself, therefore activities may not always be perceived as pleasurable, but sometimes as demanding or stressful (Romero-Martínez, Hidalgo-Moreno, & Moya-Albiol, 2020). In contrast to formal volunteering, caring roles such as grandparenting or family care typically occur within close social network and are therefore linked to greater social duties (Y. Li & Ferraro, 2005). Furthermore, the form, timing, and frequency of engagement in family care and grandparenting is often not predictable or controllable, and not always fully voluntary. Involuntarily prosocial behaviour usually has less favourable outcomes for an individual (Kim & Morgül, 2017). Therefore, prosocial activities may be less beneficial for mental health than leisure activities, which may also lead to less positive outcomes in terms of cognitive health. Results of previous studies were mixed: Volunteering may enhance well-being, but can also be taxing to a person particularly when it is highly time-consuming (Y. Li & Ferraro, 2005; Piliavin & Siegl, 2007). Becoming a grandparent may lead to increases in mental health (Kalmijn & De Graaf, 2012), but little is known about the impact of taking care of one's grandchildren. Transitioning into family care has often been linked to increased depressive symptoms (Kaschowitz & Brandt, 2017; Marks, Lambert, & Choi, 2002; Zwar, König, & Hajek, 2020). As depressive symptoms have been linked to cognitive declines (Wilson et al., 2002), particularly highly-intensive family care may therefore be negative for one's cognitive health (Romero-Martínez et al., 2020). Taken together, the effects of volunteering, grandparenting and family care on cognitive health via mental health may be less positive, compared to leisure activity. In addition to the effects of the activity itself, engagement in such activities may prevent individuals from engaging in other, more health-promoting activities. From a theoretical perspective, it is less obvious how cognitive health may be affected by prosocial activities compared with leisure activity.

As shown above, the prosocial activities included in the present study do not only differ from leisure activity, but also from each other in important aspects. For instance, volunteering allows for more control over initiation and timing of the activity, whereas grandparents and family caregivers often have to spontaneously react to their family member's needs (Roundtree & Lynch, 2006). Second, family care (and to a smaller degree, grandparenting) requires a larger adjustment of life structures than volunteering and quitting a dissatisfactory voluntary engagement is likely to be easier than stopping caring for grandchildren or family members. Finally, grandparents and family caregivers have, in contrast to volunteers, a pre-existing personal relationship to the person cared for. A major difference between family caregiving and grandparenting is that grandchildren will grow up and become more independent, while care recipients become increasingly dependent (Roundtree & Lynch, 2006). Therefore, it is important to investigate those activities separately.

Previous results on the association of prosocial activities and cognitive ageing

Compared to leisure activity, few studies have investigated the association of volunteering, grandparenting or family care with cognitive ageing. Most research is based on cross-sectional data and/or small samples. When longitudinal data have been used, it has rarely been investigated if prosocial activity predicts changes in cognitive performance over time or vice versa. Furthermore, there is limited research looking at different prosocial activities in the same dataset to rule out that different effects for different activities are the result of differences in sample characteristics. Our study aims to fill these research gaps by using a large, longitudinal dataset and investigating associations of cognitive performance with the three activities—volunteering, grandparenting and family caregiving—in the same sample. We test cross-sectional and longitudinal change-change associations, as well as considering how activity predicts changes in cognitive performance over time and vice versa.

Studies investigating the cross-sectional association of prosocial activity and cognitive performance typically find that *volunteering* (Guiney, Keall, & Machado, 2021; Schwingel, Niti, Tang, & Ng, 2009) or *grandparenting* (Arpino & Bordone, 2014; Burn, Henderson, Ames, Dennerstein, & Szoeke, 2014; McKay & Nadorff, 2020) is associated with better cognitive health. Less research is available on *family caregiving*, and many previous studies have only considered caregiving from partners of people with dementia (Allen et al., 2017). This type of family care has specific challenges which may make it unique (Zwar et al., 2018). A systematic review showed that caregivers of people with dementia performed worse than non-carers on several cognitive tests (Allen et al., 2017). However, studies that include caregivers for individuals with other health conditions provide mixed results, with higher performance among caregivers in some, and lower performance in others (García-Castro, Bendayan, Dobson, & Blanca, 2021; S. Lee, Kawachi, & Grodstein, 2004; Mallya & Fiocco, 2018). Therfore, we do not state a directional hypothesis on the association of family caregiving and cognitive performance. Based on previous studies, we assume:

H1: Individuals who volunteer (H1a) or engage in grandparenting (H1b) will show better cognitive performance.

H1c: There are differences in processing speed among those who are engaged in family caregiving and those who are not.

Several longitudinal studies reported that individuals who continue to engage in volunteering, grandchild care, or family care also better maintain cognitive health (Bertrand et al., 2011; Hughes, Flatt, Fu, Chang, & Ganguli, 2013; Infurna, Okun, & Grimm, 2016; Schwingel et al., 2009; Sneed & Schulz, 2017; Xu, 2022; Zwar et al., 2018). The longitudinal effects of different types of family care on cognitive performance have already been investigated once in the dataset used for this study (Zwar et al., 2018). The authors used a fixed effects regression approach, which showed that participants displayed better cognitive performance at time points when they were looking after someone, but there were no significant associations with other types of caregiving such as nursing activities (which we focus on in the present study) or helping around the house. Long-term change was not considered in that study. Taken together, we assume:

H2: Individuals with a higher proportion of volunteering (H2a), grandparenting (H2b) and caregiving (H2c) over time will show increases (or less decline) in cognitive performance.

As mentioned above, a problem in previous studies with correlated change relates to determining the direction of effects. Reverse causation is possible – higher cognitive abilities allow individuals to stay more active in different domains, and greater declines in cognitive functioning are likely to lead to less engagement (Gow et al., 2012; Gow, Pattie, & Deary, 2016). Furthermore, even in the absence of causal effects, positive cross-sectional associations could be present due to "preserved differentiation" (Bielak & Gow, 2022; T. A. Salthouse, 2006): Those with higher cognitive abilities may have always been more active in prosocial activities, for example because they have more physical and economic resources, and this advantage could be preserved over time (Bielak, Cherbuin, Bunce, & Anstey, 2014). Likewise, even if activity and cognition are associated longitudinally at the between-person or within-person level (Lindwall et al., 2012), this may be an indicator of global age-related or terminal decline, as change in many aspects of functioning are usually coupled in later life (Duggan et al., 2019; Muniz-Terrera et al., 2017; Zammit et al., 2021).

Prospective studies, testing for the association of baseline activity and change in cognition over a longer time span, are therefore needed, although they do not allow for clear causal inference either. The few existing studies provide mixed results (Luo et al., 2019; McKay & Nadorff, 2020; Schwingel et al., 2009; Tomioka, Kurumatani, & Hosoi, 2018). One of the studies that simultaneously looked at both the prosocial activity-cognition and the cognition-prosocial activity pathways found bi-directional effects of volunteering and cognitive health in the US Health and Retirement Survey (Kail & Carr, 2020). Based on theoretical considerations, we assume both directions of effects as well.

H3: Volunteering (H3a), grandparenting (H3b) and family caregiving (H3c) at baseline will be associated with increases (or less decline) in cognitive performance.

H4. Higher cognitive performance at baseline will be associated with a higher proportion of volunteering (H4a), grandparenting (H4b) and family caregiving (H4c) over time.

The gendered nature of prosocial activity in older age

The role of gender in investigations of prosocial activities in old age cannot be ignored. Due to different and still persistent gender role expectations – women are expected to engage in the 'private sphere' and men are expected to engage in the 'public sphere' (Miller & Borgida, 2016) - men and women differ in their frequency of engagement in different types of prosocial activities over the life span. Although gender differences are decreasing, in Germany, men have been more engaged in formal volunteering than women over the last few decades (Simonson, Kelle, Kausmann, & Tesch-Römer, 2022b). In contrast, women have been more engaged in grandparenting and family caregiving (Klaus & Vogel, 2019; Mahne & Klaus, 2017). In fact, family caregiving has been so much more prevalent among women that several studies have solely focused on women's experiences, meaning men's experiences are lacking in the literature (Houde, 2002; Zwar et al., 2018).

Furthermore, there are gender differences in the way men and women engage in prosocial activities. For example, previous studies found that men are more likely than women to be in leading positions when volunteering formally (Erlinghagen, Şaka, & Steffentorweihen, 2016). At least in Germany, women seem to be more engaged in social and family-related organizations, whereas men are more engaged in organizations dedicated to sports or rescue services (Simonson et al., 2022b). When men engage in grandparent care, it often includes less routine care activities (i.e., physical care and accompanying care) compared to women (Craig & Jenkins, 2016). Women as family caregivers do not only provide more hours of care, they also seem to engage more in tasks of personal care than men who are caregivers, who engage more in organizational work (Auth, Dierkes, Leiber, & Leitner, 2016; Deufert, 2013; Ehrlich, 2019; Sharma, Chakrabarti, & Grover, 2016). Women who are caregivers also seem to experience more negative health effects than men (Pinquart & Sörensen, 2003).

Previous studies looking at gender differences in the effects of prosocial activities on cognition reported mixed results, with some studies finding similar effects for men and women (Arpino & Bordone, 2014), and some finding stronger associations among women (Proulx, Curl, & Ermer, 2018; Zwar et al., 2018). We will therefore not postulate a directional hypothesis, but test if associations are the same among both men and women in our sample.

H5: There will be gender differences in the association of activities and processing speed.

The present study

In the present study, we investigated the longitudinal association of prosocial activity and cognitive performance in a population-based German sample of older adults. We do not focus on causal inference, but rather conduct descriptive research, using a parallel growth curve approach (see (Hamaker, Mulder, & van Ijzendoorn, 2020) for the distinction of description, prediction and causation in research). As a facet of cognitive performance, we used speed of processing, which is one of the most common outcomes in cognitive ageing studies (Hoyer, Stawski, Wasylyshyn, & Verhaeghen, 2004) and has even been seen as a possible driver of global cognitive ageing (Deary, Johnson, & Starr, 2010; Finkel, Reynolds, McArdle, & Pedersen, 2007). We distinguished volunteering, grandparenting and family caregiving and tested for gender differences.

Methods

Transparency and Openness

The study was not pre-registered. Below, we report how we determined our sample size and describe all data exclusions. The German Ageing Survey is available for the scientific community free of charge and we provide a SPSS syntax to generate our study sample, as well as Mplus input files to run all models (https://osf.io/7mdk3/, Henning, 2023). For reasons of data protection, signing a data distribution contract is required before data can be obtained[1].

Participants

We used data from four waves of the German Ageing Survey (DEAS) in 2008, 2011, 2014 and 2017. The DEAS is a longitudinal survey of the second half of life (Klaus et al., 2017). There is no ethical approval for the DEAS, as such an approval is not mandatory for general surveys in Germany. In 1996, 2002, 2008 and 2014, four separate representative samples of the German population aged 40- to 85-year-old were drawn, assessed with computer-assisted interviews, and re-interviewed on each consecutive measurement point. In 2011, 2017 and 2020/21, additional panel interviews without new samples were conducted. We focus on the waves from 2008 to 2017 because of the constant intervals between assessments. The assessments in 2020/21 were not included in our analyses because these

[1] https://www.dza.de/en/research/fdz/german-ageing-survey/access-to-deas-data

were conducted via phone and did not include cognitive tests. Our sample consisted of *n* = 8,129 individuals at baseline (2008), of which *n* = 4,160 participated in 2011, *n* = 3,723 in 2014, and *n* = 3,074 in 2017. We further restricted the sample to those who completed the cognitive test on at least one occasion (*n* = 6,915). Of those, *n* = 2,745 participants completed cognitive tests at one, *n* = 1,309 at two, *n* = 1,489 at three, and *n* = 1, 372 at all four time points.

Attrition analyses showed that, compared to those who participated only once, the longitudinal sample was significantly younger ($t(3{,}935.02) = 4.05$, $p < .001$, $d = 0.11$), showed better speed of processing ($t(4{,}194) = -8.85$, $p < .001$, $d = 0.24$), less depressive symptoms ($t(4{,}057{,}20) = 3.08$, $p = .002$, $d = 0.08$), and less health problems ($t(4{,}074.77) = 2.82$, $p < .005$, $d = 0.07$) at baseline. They were also more likely to be highly educated ($\chi^2(1) = 128.23$, $p <. 001$, $OR = 1.87$), working for pay ($\chi^2(1) = 34.80$, $p <. 001$, $OR = 1.36$), and to be volunteering ($\chi^2(1) = 93.29$, $p <. 001$, $OR = 2.05$), or grandparenting ($\chi^2(1) = 24.06$, $p <. 001$, $OR = 1.43$), but did not differ from the longitudinal sample in terms of gender ($\chi^2(1) = 1.75$, $p =.186$, OR = 1.07), or likelihood of family caregiving ($\chi^2(1) = 2.45$, $p =. 124$, OR = 1.22). All effect sizes (*ds* = 0.07-0.24, *ORs* = 1.07-2.05) were small, in line with usual guidelines (i.e., all $d < 0.3$ (Cohen, 1992), and all OR < 3.47 (Chen, Cohen, & Chen, 2010)), which suggests a low likelihood of attrition bias in our results.

Measures

Speed of processing. Speed of processing was assessed with the digit symbol substitution test (Wechsler, 1956). Participants were given a list showing how nine symbols matched the digits 1-9. Next, they were presented a list of digits and were asked to complete as many matching symbols as possible within 90 seconds. Our outcome was the number of correct responses. The test has been used in previous studies based on the DEAS (Seidler & Wolff, 2017; Wettstein, Spuling, Cengia, Nowossadeck, & Tesarz, 2020; Zwar et al., 2018).

Prosocial activities. For all three activities, we used a dichotomous variable for assessing activity vs. inactivity (0/1). Concerning *volunteering*, participants were asked about membership in organizations for senior citizens or other organizations. They could name several organizations. For each organization they were members of, they were asked if they volunteered. More information on the voluntary activities can be found in the supplementary materials (part 5). Concerning *grandparenting,* participants were asked if they took care of children, and if this meant their own grandchildren. Regarding *family care*, participants were asked if they supported persons due to their poor state of health. If they did, they were asked if this meant 1) helping to do chores, 2) supporting and guiding them, or 3) providing personal care or 4) other help and support activities. We only included those who reported 3) to narrow the analysis to personal care. Multiple answers are possible. Accordingly, respondents can for example provide personal care AND help doing the chores. That being said, we included respondents providing personal care at the very least.

Covariates. Age from the baseline interview, (as a continuous variable, centred around age 40), was included as a covariate in all analyses. We included education (ISCED categories, 0 = low or middle, 1 = high), work status (0 = not working for pay, 1 = working for pay) physical health and depressive symptoms as covariates in our analyses, all assessed in the baseline interview. Physical health was assessed by summing up the lifetime prevalence of relevant diseases, specifically high cholesterol, diabetes, high blood sugar levels, high blood pressure, heart attack/angina pectoris, cardiac insufficiency including coronary artery disease, stroke, circulatory disorders in the brain, circulatory disorders in the legs. Depressive symptoms were taken from the short-form of the Allgemeine Depressionsskala (Hautzinger, Bailer, Hofmeister, & Keller 1993), a translation of the CES-D (Radloff, 1977), which includes 15 symptoms (e.g., “I felt that everything I did was an effort”). Two of those items (“I was happy” and “I enjoyed life”) were reverse coded. The occurrence of these symptoms within the last week was rated on a scale from 1 = rarely or none of the time (less than 1 day) to 4 = most of the time (5 to 7 days). The responses were recoded to 0 - 3. Table 1 shows descriptive statistics for the covariates in 2008 by gender.

[Please insert Table 1 here]

Analysis

Change in activity and processing speed

As a first step, we were interested to investigate gender-specific trajectories of prosocial activities and processing speed in univariate models. To illustrate change in processing speed across gender, age and time, we used a latent growth curve in a structural equation model framework (Ram & Grimm, 2007) in Mplus V. 8.4 (Muthén & Muthén, 2020). Our baseline model for the whole sample included an intercept, depicting baseline levels, as well as a linear slope factor, which referred to the average linear change in processing speed over time. To allow for inter-individual differences, these parameters were modelled as random effects. We further followed Byrne and Crombie (2003) and tested for linearity of change, independence and homoscedasticity of measurement errors. Adding a quadratic slope factor, showing nonlinear change, significantly increased the model fit, showing that change was better analysed by accounting for nonlinear change ($\Delta\chi^2(4) = 105.23$, $p < .001$, $\Delta BIC = 86.10$). However, we had to set the (non-significant) variance of the quadratic slope to zero to avoid problems with a non-positive definite latent variable covariance matrix. This did not negatively affect model fit ($\Delta\chi^2(3) = 2.81$, $p = .421$). Adding intercorrelations of neighboured error terms did not show significant associations and did not increase model fit significantly, compared to a model in which these correlations were set to zero ($\Delta\chi^2(3) = 2.81$, $p = .421$), and other measures of model fit decreased ($\Delta BIC = 23.22$, $\Delta RMSEA = 0.017$; $\Delta SRMR = 0.001$), demonstrating independence of measurement errors. Finally, we tested for homoscedasticity by comparing a model with freely estimated error variances to a model with the same error variances. Setting the error variances equal over time led to a significant decline in model fit ($\Delta\chi^2(3) = 48.74$, $p < .001$), therefore we estimated them freely over time (i.e., with heteroscedasticity). To account for this, we used the maximum likelihood estimator with robust standard errors (mlr). Level and change were predicted by age.

We ran a multigroup model to investigate gender differences in level and change in processing speed, as well as gender differences in age effects. Following Grimm, Ram, and Estabrook (2016), we started with a model in which all means, variances and covariances were estimated to be the same across genders. We adjusted the procedure recommended by Grimm et al. (2016) for a model with a covariate (age) and released constraints stepwise: first means and intercepts, next the level-slope covariance, then effects of age on intercept and slopes, and finally residual variances of level, slope and the time-specific residual errors. For every step, we tested if there were significant increases in χ^2 values. If there were, we fixed the single parameters stepwise to be the same again, to see which parameter was responsible for the increase.

A similar model was run to examine change in participation in activities (yes/no), but here we modelled binary growth curves using the logit link in MPlus (T. K. Lee, Wickrama, & O'Neal, 2018) and predicted level and change by age[2]. Again, we ran multigroup models to test for differences between genders. Here we used Satorra-Bentler scaled (mean-adjusted) -2*loglikelihood tests to compare models. Although including a quadratic slope increased the model fit significantly for all three activities (volunteering: TRd (4) = 36.94, $p < .001$, grandparenting: TRd (4) = 33.60, $p < .001$, family care: TRd (4) = 46.86, $p < .001$), we had to use models with only a linear slope for the activities because of nonconvergence issues in the more complex multigroup models.

[2] These models had slightly smaller samples than the final, bivariate models on activity and cognition, as n= 3 individuals had no data on volunteering, n = 83 individuals had no data on grandparenting, and n = 155 had no data on family care and were thus excluded from the respective models.

Associations of Activity and Processing Speed

In a second step, we used three separate parallel growth curve models in which level and change in processing speed and prosocial activity (i.e., volunteering, grandparenting, and family care) were correlated, controlling for effects of age. Again, a multi-group approach (men vs. women) was used and the gender differences from the univariate models were kept.

To investigate H5, gender differences in the bivariate associations of processing speed and activities (i.e., the associations relevant to our hypotheses) were tested using Satorra-Bentler scaled (mean-adjusted) -2*loglikelihood tests, comparing a model with different associations to a model with the same associations across genders. If the effect with different effects showed a better fit, this would be evidence for gender-specific associations. A positive correlation of intercepts would support H1a and 1b, that volunteering and grandparenting are associated with higher processing speed. Positive correlation of slopes would support H2a-c, that higher proportions of volunteering, grandparenting and family care over time are associated with less cognitive decline. Positive correlations of intercepts and slopes would support H3a-c (i.e., association of baseline prosocial activity and change in processing speed) and H4a-c (i.e., association of baseline processing speed and change in prosocial activity).

Models were repeated with covariates added (education, work status, health risk factors, depressive symptoms). As a sensitivity analysis, we repeated all models only including participants aged 65 and older (n = 3,028, with covariates n = 2,925), as cognitive decline is especially pronounced in old age.

We used the full information maximum likelihood estimator (FIML) to deal with missing data (Enders, 2010). However, we could not use FIML for the models with covariates, as we faced non-convergence due to the complexity of the models. Therefore, 198 individuals with missing data on covariates were excluded in these models. When conventional fit indices were available (i.e., in the univariate growth curve), we used the comparative fit index (CFI), the standardized root mean residual (SRMR) and the root mean square error of approximation

(RMSEA) as measures of global model fit. Marsh (2007) recommended that CFI values around .900 and SRMR and RMSEA values around .080 indicate acceptable model fit. The alpha level was set to 0.05.

Results

Processing Speed across Gender, Age and Time

To investigate and illustrate gender- and age-specific change in processing speed, we used a multigroup latent growth curve with age as a predictor of intercept and slopes for men and women. Test statistics, comparing different models with increasing complexity can be found in the supplementary materials (Part 1.1). All parameters of this final model can be found in the supplementary materials (Table S1).

In the final model, intercepts differed significantly between genders, which means that women had higher baseline levels in processing speed at age 40 ($Intercept_{\text{Level}}$ = 56.78, *SE* = 0.43, $p < .001$) than men ($Intercept_{\text{Level}}$ = 52.18, *SE* = 0.46, $p < .001$). Women and men at age 40 did not differ in terms of average linear increase ($Intercept_{\text{Slope}}$ = 3.39, *SE* = 0.26, $p < .001$). The nonlinear decrease was steeper for men ($M_{quadraticSlopeWomen}$ = -0.74, SE = 0.04, $p < .001$ vs. $M_{quadraticSlopeMen}$ = -0.85, SE = 0.06, $p < .001$).

Age differences in processing speed at baseline were larger among women (*B* = -0.59, *SE* = 0.02, $p < .001$) than among men (*B* = -0.51, *SE* = 0.02, $p < .001$), but age differences in linear change were the same (*B* = -0.06, *SE* = 0.01, $p < .001$). Figure 1 shows change over time by age and gender, based on predicted values. Panel A shows three groups (40, 60 and 80 years old at baseline) with time of assessment as the x-axis; Panel B shows change in six age groups (age 40, 49, 58, 67, 76, 85 at baseline) with age as the x-axis. The age-related cognitive decline is clearly visible in both panels.

[Please insert Figure 1 here]

Prosocial Activity across Gender, Age and Time

Results of all multigroup model comparisons and all coefficients for the final models can be found in the appendix (1.2-1.4). Women had a lower likelihood of *volunteering* at baseline (Women: $Intercept_{Level}$ = -3.84, SE = 0.23, p < .001 vs. Men: $Intercept_{Level}$ = -2.76, SE = 0.46, p < .001), but it increased more strongly over time (Women: $Intercept_{Slope}$= 0.43, SE = 0.10, p = .012 vs. Men: $Intercept_{Slope}$= -0.20, SE = 0.10, p = .034). Age effects on level and slope were the same across genders, with older participants being less likely to volunteer at baseline (B = -0.03, SE = 0.01, p < .001) and over time (B = -0.01, SE = 0.00, p < .001).

Women were more likely to be *grandparenting* at baseline (Women: $Intercept_{Level}$ = -4.87, SE = 0.27, p < .001 vs. Men: $Intercept_{Level}$ = -6.41, SE = 0.30, p < .001), but the increase over time was the same for both genders ($Intercept_{Slope}$= 0.94, SE = 0.12, p < .001). For both genders, grandparenting was more likely at higher ages, but the effect was stronger for men (Men: B = 0.09, SE = 0.01, p < .001 vs. Women: B = 0.05, SE = 0.01, p < .001). The increase over time was weaker at higher ages (B = -0.04, SE = 0.00, p < .001).

Women were more likely to be a *family caregiver* at baseline (Women: $Intercept_{Level}$ = -5.09, SE = 0.35, p < .001 vs. Men: $Intercept_{Level}$ = -7.39, SE = 0.44, p < .001), but the increase over time was the same for both genders ($Intercept_{Slope}$= 0.37, SE = 0.18, p = .037). The likelihood of being a *family caregiver* at baseline was higher at older ages for men, but not for women (Men: B = 0.04, SE = 0.01, p < .001 vs. Women: B = -0.01, SE = 0.01, p = .139); women are more likely to already care in midlife, probably often for their parents. Age effects on the slope were non-significant (B = 0.00, SE = 0.00, p = .839).

We illustrate the rates of volunteering, grandparenting and family care in five age groups (40-49, 50-59, 60-69, 70-79, 80-85) per gender over time in Figure 2-3, based on percentages of activity, because interindividual differences in change are more complicated to illustrate based on logistic growth curves. There is a high attrition rate among those aged 80-85 at baseline, therefore the frequencies are probably less reliable than others. In this group, of initially 449, only 78 participants still participated in 2017. The graphs show that patterns differ between activities, gender, and age. Volunteering was the most frequent activity, followed by grandparenting and family care. Volunteering was most frequent in the 40's to 60's, grandparenting in the 60's. The proportion of those engaged in family care increased among men from their 70's on, but for women it was particularly prominent in their 50's and 60's.

[Please insert Figure 2 here]

[Please insert Figure 3 here]

Associations of Prosocial Activity and Processing Speed

We started with three separate multigroup (men vs. women) parallel latent growth curve models for processing speed and dichotomous variables for engagement in each of the prosocial activities, controlling for age effects. The constraints from the earlier steps with only activity or processing speed were retained. The bivariate covariances, included to address our hypotheses, were fixed to equality and we tested if releasing them led to a better model fit, which would show that genders differed in the associations of activity and processing speed (H5).

Next, we added effects of further covariates. Again, we computed model tests in univariate models first, to see which parameters differed across genders when controlling for covariates (see supplemental materials part 1.5-1.8 for results). Table 2 shows the results of the final models, with and without controlling for covariates. Effects of covariates can be found in the supplementary materials (Tables S5-S7).

[Please insert Table 2 here]

Volunteering. Associations of volunteering and processing speed could be set equal for both genders without a significant loss in model fit (TRd (4) = 1.02, p = .907). This means that, in contrast to H5, associations of volunteering and processing speed did not differ by gender. There was a significant, positive intercept-intercept association, which means that, in line with H1a, those who volunteered showed higher levels of processing speed at baseline (*B* = 7.79, *SE* = 0.93, $p < .001$). This association is illustrated in Figure 4.

[please insert Figure 4 here]

When additionally controlling for education, work status, physical health, and depressive symptoms, associations of volunteering and processing speed could be set equal across genders again (*TRd* (4) = 2.23, $p = .693$), in contrast to H5. The association of volunteering and processing speed at baseline remained significant (*B* = 5.06, *SE* = 0.87, $p < .001$). However, hypotheses H2a, H3a and H4a about longitudinal associations of level and change were not confirmed.

Grandparenting. Associations could be set equal between genders without significant loss in fit (*TRd* (4) = 1.44, $p = .231$), in contrast to H5. Higher processing speed at baseline was related to grandparenting over time (*B* = 1.25, *SE* = 0.48, $p = .009$), in line with H4b. The other hypotheses were not confirmed. When covariates were included, associations could be set equal between genders again (*TRd* (4) = 1.21, $p = .876$) and none of them was significant any more.

Family care. Associations of family care and processing speed could be set equal without significant loss in fit (*TRd* (4) = 0.37, $p = .985$). None of the hypotheses were confirmed as none of the associations were significant, in contrast to H1c,H2c,H3c and H4c. When further covariates were included, bivariate associations could be set equal across genders again (*TRd* (4) = 1.30, $p = .861$), though again, none of the associations were significant.

Sensitivity analyses: Including only individuals aged 65 and older

We repeated the models, only including individuals aged 65 and older, as the associations may be stronger once cognitive decline was more pronounced. Results from model tests and effects of covariates can be found in the supplementary materials (part 3-4).

Volunteering. Associations of interest could be set equal between genders (*TRd* (4) = 2.61, $p = .625$). In line with H1a, volunteering at baseline was associated with higher processing speed (*B* = 9.03, *SE* = 1.42, *p* < .001). In contrast to H2a, H3a and H4a, there were no further significant associations. When controlling for covariates, associations could be set equal again (*TRd* (4) = 5.29, *p* = .259). The level – level association (*B* = 6.66, *SE* = 1.39, *p* < .001) remained significant. In line with H2a, there was a significant positive slope-slope association, which means that a higher proportion of volunteering over time was associated with stronger increases or less cognitive decline (*B* = 0.51, *SE* = 0.24, *p* = .036). This effect is visualized in Figure 5.

[please insert Figure 5 here]

Grandparenting. Associations of interest could be set equal across genders (*TRd* (4) = 0.58, *p* = .965). None of the associations were significant. Repeating the model with covariates, we could set the associations to be equal again (*TRd* (4) = 0.68, *p* = .954). This model did not show significant associations either.

Family Care. Associations of interest could be set equal across genders (*TRd* (4) = 2.42, *p* = .659). No significant associations were found. Repeating the model with covariates, associations could be set equal again (*TRd* (4) = 2.49, *p* = .646). In contrast to hypothesis 4c, higher speed of processing at baseline was significantly negatively associated with family care over time (*B* = -2.43, *SE* = 0.95, *p* = .010).

[please insert Table 3 here]

In Table 4, we show an overview of the models with regard to the hypotheses of the study.

[please insert Table 4 here]

Discussion

In the present study, we investigated the nine-year longitudinal association of three prosocial activities (volunteering, grandparenting, family care) and processing speed in a population-based sample aged 40-85 at baseline. We approached the topic from a gender perspective, given that the rates of activity, but also their intensity and content over the life course, vary a lot between genders.

Is prosocial activity associated with interindividual differences in cognitive ageing?

Our sample showed clear evidence of age-related cognitive decline. Furthermore, longitudinal change over time did not completely match cross-sectional age differences at baseline. This may be a sign of panel selectivity if people with stronger declines were less likely to return in subsequent waves, but samples may typically be more selective with regards to level in cognitive performance than change (T. A. Salthouse, 2019). It may also show practice effects. Alternatively, it may be a sign of cohort differences, which have been found in this dataset in a recent study (Beller, Kuhlmann, Sperlich, & Geyer, 2022), with later birth cohorts performing better at the same age (see e.g., (Brailean et al., 2018; Thorvaldsson, Karlsson, Skoog, Skoog, & Johansson, 2016)). However, there were interindividual differences in both level and change in speed of processing, which offered the opportunity to look at associations of prosocial activity and speed of processing over time.

The only association present across all model specifications was the positive cross-sectional association of volunteering and processing speed: In line with previous studies (Guiney & Machado, 2017) and H1a, those who volunteered showed better processing speed. Nevertheless, it is unclear if these effects demonstrate benefits of volunteering, or rather selection into volunteering. Longitudinal effects were only present among those aged 65 and older, consistent with the idea that more pronounced cognitive declines typically start around this age (T. Salthouse, 2012). In this group, continuing or starting to volunteer over time was associated with less reduction in processing speed, in line with H2a, but only if covariates were controlled for. This offers some support for the use-it-or-lose-it theory (Bielak & Gow, 2022): Staying active (e.g., by volunteering) may help to preserve one's cognitive skills in older age by exercising them in everyday life. However, the reason for this association may also be that volunteering is only possible if processing speed allows it, or the association may be driven by changes in physical or mental health over time, which influences both processing speed and the ability to volunteer. Models such as bivariate dual change scores may provide some insights about the temporal order of volunteering and processing speed (Windsor, Gerstorf, Pearson, Ryan, & Anstey, 2014), but are currently not easy to conduct with dichotomous variables such as participation in prosocial activity. Furthermore, as this association was only significant when controlling for covariates, it does not seem to be very stable and it may be a spurious correlation.

In contrast to what we may expect if volunteering protected against cognitive decline (H3a) (Gow et al., 2012), volunteering at baseline was not associated with change in cognition over time. One explanation is that volunteering only protects against cognitive decline while people maintain it, in line with the "use it or lose it" approach to cognitive ageing (Bielak & Gow, 2022). Alternatively, the long timespan (nine years) may be responsible for the lack of effects; volunteering may protect cognitive health for months or a few years. Studies over shorter periods may show different results. Interestingly, we did not find evidence for processing speed as a predictor of volunteering over time, in contrast to H4a.

Taken together, our paper provides only mixed support for a beneficial role of volunteering for cognitive ageing, given the lack of protection against log-term decline, in contrast to earlier studies, arguing that volunteering is a promising tool to support cognitively healthy ageing (Guiney & Machado, 2017). Our paper joins recent studies on the association of volunteering and well-being, which have pointed out that the earlier literature may have exaggerated positive effects of volunteering on the individuals by not considering within-person associations and selection into volunteering (Bjälkebring et al., 2021; Lühr, Pavlova, & Luhmann, 2021). We assume that the context of and motivation for the individual volunteering activity must be considered. More studies are needed to investigate under which circumstances volunteering can be of benefit for cognitive health.

For the other two activities, we found no stable associations, although both activities include physical activity and are potentially rewarding, but also emotionally challenging, and may thus have an impact on processing speed. Processing speed at baseline was negatively related to continued family care over time, once covariates were taken into account. This may show that those with higher processing speed where less likely to start or continue caring, potentially because better means to afford professional care. Given that the effect was only present in models with covariates, it may also be a spurious association. Our findings are consistent with results from Zwar and colleagues (2018), who only found significant effects for looking after someone, not for other types of family care, including personal care in the German Ageing Survey.

Two reasons may explain the absence of consistent results: First, we would expect less selection of cognitively healthier participants into grandparenting and family care, compared to volunteering. Second, as involvement in these activities are often less under the individual control than leisure activities or volunteering, and can also be associated with stress and mental health problems, the assumed general positive effects of activity engagement may not apply to those activities, but they may on average also be not challenging enough to be connected to cognitive decline.

Again, associations may depend on the individual context of involvement– how much control carers have over the content, intensity or frequency of their activity, what they need to do and how much support from others (e.g., spouses, family, or, regarding family care, professional services) they receive.

The gender perspective

In our models, bivariate associations of processing speed were the same for men and women, in contrast to our hypothesis H5. We had anticipated different associations, given that men and women differ in the way they engage in the prosocial activities considered; for example, women provide more physical care for grandchildren (Craig & Jenkins, 2016).

However, the activities seem to be similar enough to be associated with cognitive health in the same direction and magnitude. Nevertheless, gender remains important because we found gender differences in levels and age-related change in processing speed and prosocial activities.

In line with earlier findings in the literature (Roivainen, 2011), women had higher processing speed than men. Interestingly, the differences were larger among the latest birth-cohorts, which may be explained by decreases in educational inequalities between men and women over time. With more women receiving better education, the gap may have increased. Similar findings have been shown in a recent study in a Dutch sample (Nooyens et al., 2022). Whereas linear change was similar between genders, the drop at the end of the nine-year period (i.e, the quadratic change component of the growth curve model) was slower among women. Findings on gender differences in cognitive decline are inconclusive, but our results are in line with results in an English sample reporting slower decline in women, compared to men, in processing speed over eight years (Zaninotto, Batty, Allerhand, & Deary, 2018).

The distribution of prosocial activity over the second half of life varied by activity and gender. Women were more active concerning grandparenting and family care over the second half of life, whereas men were more likely to volunteer. For all activities, frequencies of engagement were lower among those in their 70s, probably because of health declines. From a gender perspective, it is worth noting that although activity patterns and level and change in processing speed varied between genders, but the associations of activity and processing speed were the same.

Importantly, formal volunteering, which shows more (although not convincing) associations with cognitive health both in the literature and in our analyses, is more common among men in Germany, whereas family care and grandparenthood, which have even be related to worse cognitive health in some studies (Romero-Martínez et al., 2020), are much more common among women. It has long been discussed that differences in activity are likely to be caused by normative gender roles (Miller & Borgida, 2016) and the inequality in access to, or involvement in, different forms of prosocial activity may have negative consequences for women (Pinquart & Sörensen, 2003).

Strengths and Limitations

The present study has several strengths, including the large, age-diverse population-based sample, which may be less biased than convenience samples, and the focus on longitudinal within-person change instead of cross-sectional comparisons. Furthermore, we focused on three different types of activity and considered gender differences. A further strength is the long follow-up period – four assessments over a nine-year period.

However, there are also some weaknesses. First, our analyses do not allow causal conclusions. Although they offer interesting descriptive evidence, our associations do not mean that there are causal effects of volunteering on cognitive health, and the absence of effects does not mean there are no causal effects. Other designs, for example RCTs (Jiang et al., 2021) or instrumental variable models, if strong instruments are available (Gupta, 2018), are needed for causal conclusions. Second, we used broad measures of activity, overlooking differences in the content and context of each activity. Future studies will benefit from a more in-depth investigation of when and for whom volunteering, grandparenting or family care are associated with better or worse cognitive performance. Third, we investigated only one type of cognitive performance, processing speed, assessed by a single test. Although this is a common indicator of cognitive performance in older age and prominent in research on cognitive ageing, associations with memory or spatial ability may follow different patterns, in particular with regard to gender differences (McCarrey, An, Kitner-Triolo, Ferrucci, & Resnick, 2016). Fourth, we ran separate models for the three activities and did not consider the interplay of different prosocial activities. Fifth, our study design did not allow to investigate change over shorter periods. Prosocial activity may have benefits in the short-term, for example over several months. Datasets with more frequent assessments are needed to test this.

Finally, as common in longitudinal studies of older adults, attrition was considerable. Although the associations of attrition with our variables of interest were small, the resulting longitudinal sample is a selection of individuals with better cognitive health. It is further possible that, for example, individuals who started caring for sick family members were no longer able to participate in follow-up waves as a result of their personal commitments. Those who were caring and able to participate in the survey may thus be a particularly cognitively healthy subgroup. Future studies with lower rates of attrition should replicate our findings and may provide clearer evidence of any associations of prosocial activities and speed of processing.

Conclusion

Although many studies highlight the role of an active lifestyle for a more positive cognitive ageing, our results provide limited support for a positive association of continued engagement in volunteering, but not grandparenting or family caregiving, with cognitive ageing. Given that baseline volunteering was not associated with long-term decreases in processing speed, the associations are likely to be more complex. Although all the three activities are of great societal importance, researchers and practitioners should be careful to exaggerate their positive effects on the ageing individual.

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Tables.

Table 1. Descriptive statistics from the first wave

	Men (*n* = 3,466)	Women (*n* = 3,449)
Age (*M* (*SD*))	62.53 (11.45)	60.87 (11.53)
Education (%)	Low or middle =1,929 (55.65%)	Low or middle = 2,433 (70.54%)
	High = 1,537 (44.35%)	High = 1,016 (29.46%)
Working for pay	Yes = 1,533 (44.28%)	Yes = 1,427 (42.47%)
	No = 1,929 (55.72%)	No = 1,933 (57.53%)
Volunteering	Yes = 746 (21.56%)	Yes = 535 (15.53%)
	No = 2,714 (78.44%)	No = 2,910 (84.74%)
Family care	Yes = 104 (3.09 %)	Yes = 190 (5.79%)
	No = 3,267 (96.91%)	No = 3,091 (94.35%)
Grandparenting	Yes = 383 (11.41%)	Yes = 329 (14.46%)
	No = 2,975 (88.59%)	No = 2,931 (85.54%)
Depressive Symptoms (*M* (*SD*), range 0-40)	5.65 (5.27)	6.81 (6.43)
Diagnoses (*M* (*SD*), range 0-8)	1.15 (1.24)	0.96 (1.13)
Speed of processing (*M (SD*), range 3-92)	40.98 (13.69)	44.54 (14.45)

N = 6,915. *Note.* Data on race was not available in the dataset, which is common for German and European surveys.

Table 2. Associations of prosocial activity (yes / no) and processing speed

	Volunteering				Grandparenting				Family Care			
	Controlling for age		Fully adjusted Model		Controlling for age		Fully adjusted model		Controlling for age		Fully adjusted model	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)
I_{PS}	52.15 (0.46)***	56.83 (0.43)***	49.50 (0.67)***	55.47 (0.63)***	52.16 (0.46)***	56.79 (0.43)***	49.50 (0.67)***	55.46 (0.63)***	52.15 (0.46)***	56.82 (0.43)***	49.50 (0.68)***	55.46 (0.63)***
I_A	-2.71 (0.20)**	-3.78 (0.22)***	-3.61 (0.34)***	-3.96 (0.33)***	-6.38 (0.30)***	-4.85 (0.26)***	-5.48 (0.36)***	-4.02 (0.40)***	-6.73 (0.41)***	-5.59 (0.37)***	-5.53 (0.36)***	-4.03 (0.32)***
S_{PS}	3.34 (0.26)***		3.27 (0.34)***		3.41 (0.26)***		3.33 (0.34)***		3.39 (0.26)**		3.33 (0. 34)***	
S_A	0.18 (0.09)	0.40 (0.10)***	0.06 (0.16)	0.44 (0.15)**	0.93 (0.11)***		0.51 (0.16)**		0.44 (0.21)*	0.41 (0.19)*	0.54 (0.16)**	
Q_{PS}	-0.84 (0.07)***	-0.73 (0.07)***	-0.83 (0.07)***	-0.71 (0.07)***	-0.86 (0.07)***	-0.75 (0.07)***	-0.84 (0.07)***	-0.72 (0.07)***	-0.85 (0.07)***	-0.74 (0.07)***	-0.84 (0.07)***	-0.72 (0.07)***
Cov(I_{PS}, I_A)	7.79 (0.93)***		5.02 (0.88)***		-1.49 (0.80)		-1.14 (0.78)		-1.31 (1.07)		-1.14 (0.78)	
Cov(S_{PS}, S_A)	0.16 (0.15)		0.18 (0.15)		-0.26 (0.18)		-0.24 (0.17)		0.33 (0.20)		-0.24 (0.17)	
Cov(I_A, S_{PS})	-0.34 (0.39)		-0.22 (0.39)		0.58 (0.36)		0.61 (0.36)		-0.39 (0.45)		0.61 (0.36)	

Cov(I_{PS}, S_A)	-0.11 (0.46)	-0.22 (0.42)	1.25 (0.48)**	0.82 (0.45)	-0.62 (0.51)	0.84 (0.45)
Residual variance I_{PS}	80.82 (3.93)***	69.23 (3.75)***	81.26 (3.94)***	69.54 (3.75)***	81.25 (3.94)***	69.54 (3.75)***
Residual variance I_A	16.57 (1.62)***	15.96 (1.58)***	10.22 (1.12)***	10.14 (1.12)***	8.93 (1.38)***	10.20 (1.13)***
Residual variance S_{PS}	2.49 (0.82)**	2.39 (0.82)**	2.56 (0.82)**	2.44 (0.81)**	2.55 (0.82)**	2.44 (0.82)**
Residual variance S_A	0.70 (0.11)***	0.71 (0.12)***	1.03 (0.16)***	0.96 (0.15)***	0.45 (0.13)***	0.96 (0.15)***
Loglikelihood	-69,925.30	-67,886.94	-67837.86	-66,950.67	-65,853.71	-65,853.71
AIC	139,910.60	135,773.71	138,002.38	133,995.34	131,767.42	131,767.42

N = 6,915 for models controlling for age, *n* = 6,717 for fully adjusted models. * $p < .05$ ** $p < .01$ *** $p < .001$ I_A = Intercept Activity, I_{PS} = Intercept Processing Speed, S_A = Slope Activity, S_{PS} = Slope Processing Speed. *Note*. Univariate intercept-slope variances, time-specific residual variances for speed of processing and effects of covariates are not displayed. Age was recoded (0 = 40 years).

Table 3. Associations of prosocial activity (yes / no) and processing speed among those 65 and older

	Volunteering				Grandparenting				Family Care			
	Controlling for age		Fully adjusted Model		Controlling for age		Fully adjusted Model		Controlling for age		Fully adjusted Model	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
I_{PS}	40.18 (0.43)***	41.97 (0.47)***	38.39 (0.54)***	45.20 (0.83)***	40.16 (0.43)***	41.96 (0.47)***	40.67 (0.57)***	44.17 (0.60)***	40.16 (0.43)***	41.95 (0.47)***	40.68 (0.57)***	44.18 (0.60)***
I_{A}	-2.63 (0.27)***	-3.33 (0.29)***	-3.60 (0.34)***		-2.11 (0.19)***		-2.34 (0.25)***		-7.06 (0.67)***		-7.58 (0.76)***	-7.25 (0.77)***
S_{PS}	2.19 (0.38)***		1.69 (0.43)***		2.28 (0.38)***		1.59 (0.44)***		2.28 (0.38)***		1.59 (0.44)***	
S_{A}	0.08 (0.13)		0.07 (0.17)		-0.09 (0.10)		-0.07 (0.14)		0.93 (0.34)**	0.17 (0.32)	0.58 (0.39)	0.76 (0.37)*
Q_{PS}	-0.71 (0.11)***		-0.66 (0.11)***		-0.73 (0.11)***		-0.67 (11)***		-0.73 (0.11)***		-0.67 (11)***	
Cov(I_{SP}, I_{A})	9.03 (1.42)***		6.66 (1.39)***		0.12 (1.02)		-0.14 (1.01)		-0.34 (2.02)		0.91 (1.81)	
Cov(S_{SP}, S_{A})	0.46 (0.24)		0.51 (0.24)*		0.10 (0.25)		0.06 (0.25)		0.40 (0.40)		0.54 (0.40)	
Cov(I_{A}, S_{SP})	-1.10 (0.63)*		-1.04 (0.65)		0.46 (0.50)		0.51 (0.50)		-0.07 (0.89)		0.34 (0.86)	
Cov(I_{SP}, S_{A})	0.22 (0.71)		-0.02 (0.65)		0.49 (0.65)		0.36 (0.62)		-1.36 (0.95)		-2.43 (0.95)*	

Residual variance I_{PS}	79.54 (6.45)***	68.42 (6.22)***	79.39 (6.44)***	68.26 (6.21)***	79.49 (6.45)***	68.26 (6.21)***
Residual variance I_A	16.08 (2.49)***	16.28 (2.59)***	7.92 (1.35)***	7.84 (1.37)***	16.13 (3.62)***	14.55 (3.31)***
Residual variance S_{PS}	3.83 (1.42)**	3.60 (1.43)*	3.74 (1.42)**	3.51 (1.43)*	3.76 (1.42)**	3.54 (1.43)*
Residual variance S_A	0.51 (0.16)**	0.53 (0.16)**	0.63 (0.17)***	0.59 (0.17)**	1.20 (0.35)**	0.92 (0.30)**
Loglikelihood	-28,694.27	-27,603.04	-28,545.13	-27,473.83	-27,174.41	-26,122.84
AIC	57,442.55	55,290.07	57,142.26	55,093.66	54,404.83	52,333.69

N = 3,038 for models controlling for age, *n* = 2,925 for fully adjusted models. *$p < .05$ **$p < .01$ ***$p < .001$ I_A = Intercept Activity, I_{PS} = Intercept Processing Speed, S_A = Slope Activity, S_{SP} = Slope Processing Speed. Univariate intercept-slope variances, time-specific residual variances for speed of processing and effects of covariates are not displayed. Age was recoded (0 =65 years).

Table 4. Hypotheses and results

	Volunteering				Grandparenting				Family Care			
Hypotheses	Controlling for age	Fully-adjusted	65+ (controlling for age)	65+ (Fully-adjusted)	Controlling for age	Fully-adjusted	65+ (controlling for age)	65+ (Fully-adjusted)	Controlling for age	Fully-adjusted	65+ (controlling for age)	65+ (Fully-adjusted)
H1: Intercept-Intercept Association	+	+	+	+	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
H2: Slope-Slope Association	n.s.	n.s.	n.s.	+	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
H3: Intercept Activity – Slope Processing Speed Association	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s	n.s.	n.s.	n.s.	n.s
H4: Intercept Processing Speed – Slope Activity Association	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	-
H5: Gender Differences in Associations	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Figure 1. Change in processing speed by age and gender

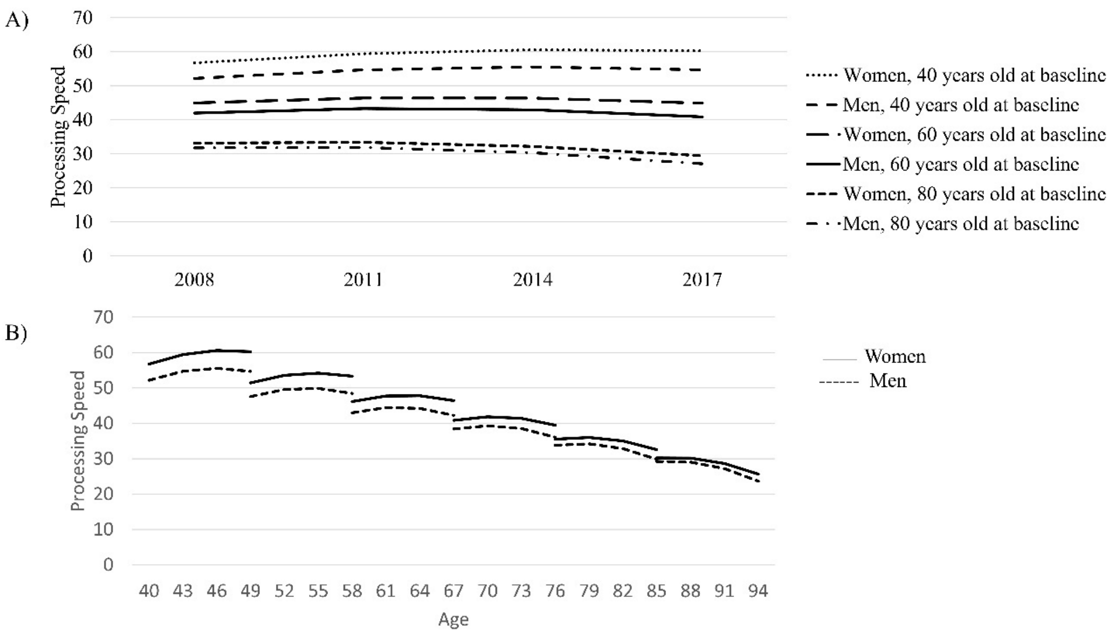


Figure 2. Prosocial activity across age groups, men

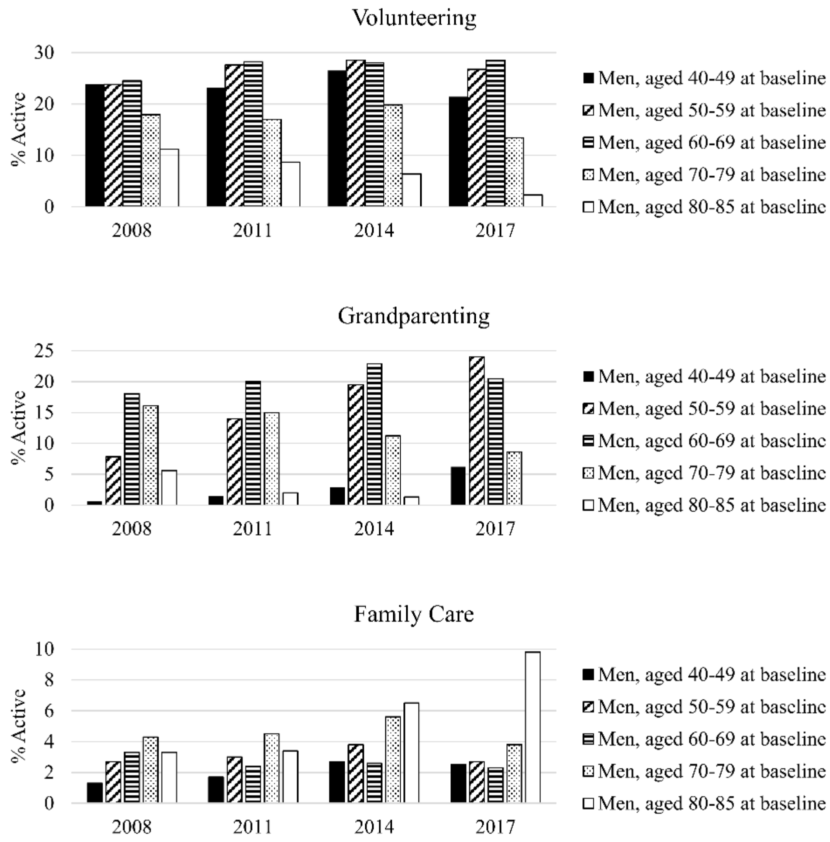


Figure 3. Prosocial activity across age groups, women

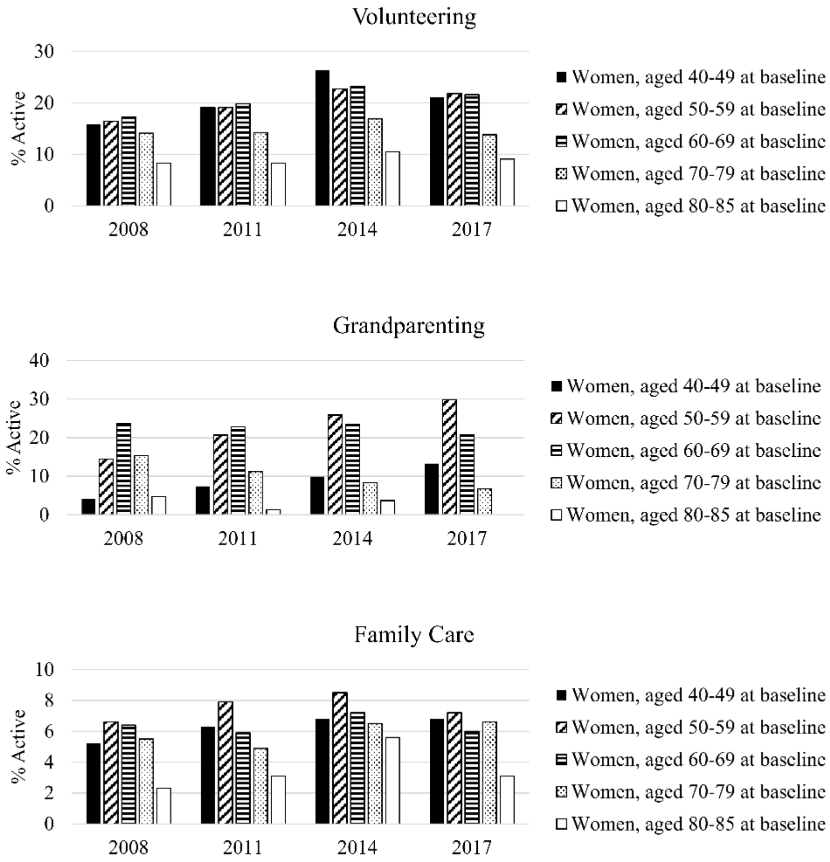
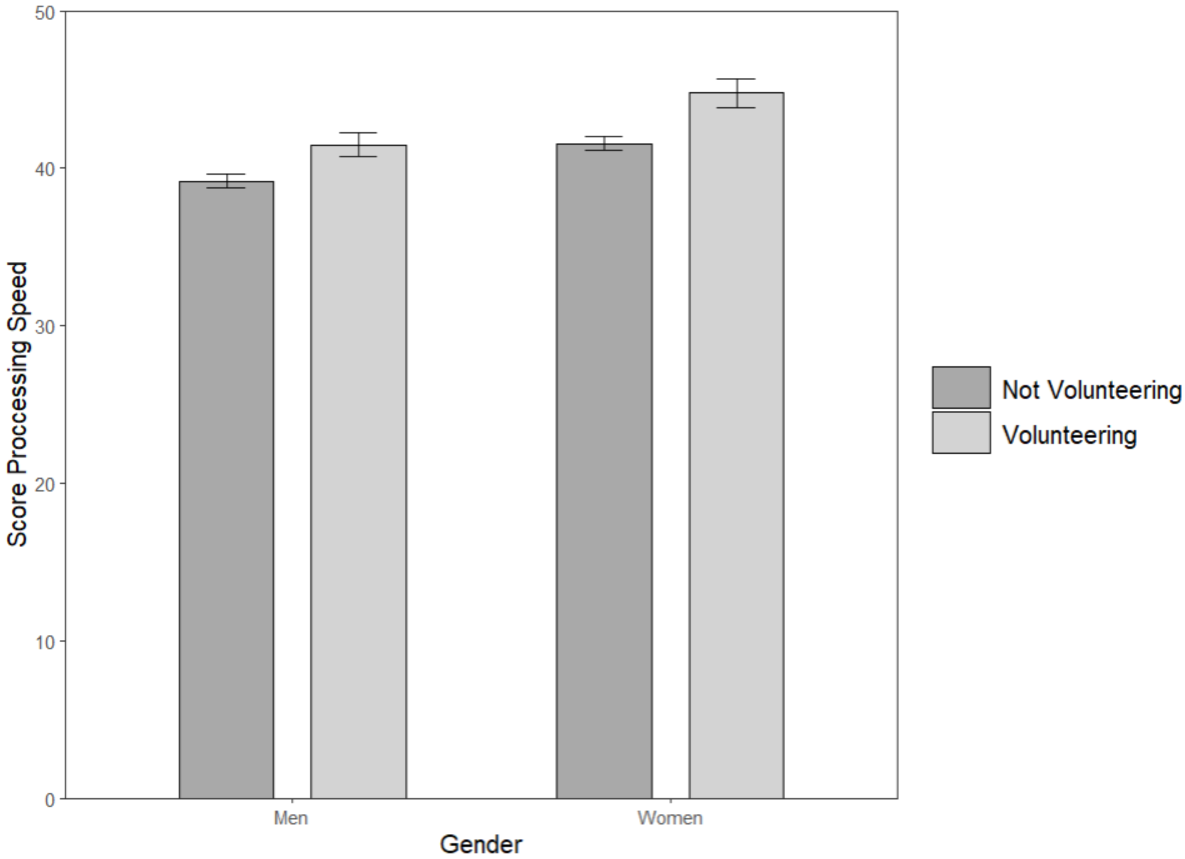


Figure 4. Association of Volunteering and Processing Speed by Gender (at age 65)



Note. Predicted values, based on linear regression, controlling for age. Age centered around 65.

Figure 5. The association of change in volunteering and processing speed among participants aged 65+.

Note. Controlling for age, education, work status, depressive symptoms and health risk factors.