European Journal of Ageing (2019) 16:317–326
https://doi.org/10.1007/s10433-019-00500-6

ORIGINAL INVESTIGATION

Longitudinal correspondence between subjective and objective memory in the oldest old: A parallel process model by gender

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Published online: 29 January 2019

Abstract
Subjective memory and objective memory performance have predictive utility for clinically relevant outcomes in older adults. Previous research supports certain overlap between objective performance and subjective ratings of memory. These studies are typically cross-sectional or use baseline data only to predict subsequent change. The current study uses a parallel process model to examine concurrent changes in objective memory and subjective memory. We combined data from two population-based Swedish studies of individuals aged 80 + years, assessed every 2 years (OCTO—3 measurement occasions, OCTO-Twin—5 measurement occasions) yielding 607 participants (66% female). The results confirmed that both objective and subjective memory declined over time. The association between the slope of objective memory and subjective memory was statistically significant for women but not for men. This pattern remained after accounting for age and depressive symptoms. Our findings suggest that, in population-based samples of the oldest old, women seem to show better metacognitive abilities in detecting and reporting changes in memory. Memory changes for men may be better identified by objective performance as their self-assessment of memory changes is not associated with actual change in memory performance.

Keywords Subjective memory · Objective memory · Oldest old · Parallel processes

Introduction

It has been well established in research that memory declines with advancing age (Johansson et al. 2004; Rönnlund et al. 2005) and that these declines are associated with negative health outcomes, such as reduced daily activities and dementia (Sliwinski et al. 2003; Willis et al. 2006). Moreover, memory is one of the greatest complaints in older individuals and is consequently one of the most studied aspects in late adulthood (Johansson et al. 1999). In addition, individuals of all ages believe that memory decline is associated with age, which coincides with these findings (Horhota et al. 2012). Researchers and clinicians typically use the complaints and subjective ratings to evaluate subjective reports which are indicative of actual impediments in memory abilities. However, complaints and an individual's ability to monitor changes in memory may not be associated with concurrent declines in objective performances.

Assessing and monitoring one's own memory abilities (subjective memory) can be informative if the assessment reflects an actual change in memory performance (objective memory). As shown in a meta-analysis by Crumley et al. (2014), most studies have found overall weak associations between subjective and objective memory when compared at the same occasion. Research on the ability to monitor memory in later adulthood has increased over the past two decades to combat any age-related changes in performances (Hertzog and Dunlosky 2011). Asking individuals how likely they will be able to remember information later is commonly used to assess subjective memory (Castel et al. 2015). This monitoring method has generated findings that

Responsible editor: Matthias Kliegel.

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suggest that older adults (60+) either tend to over-estimate (Soderstrom et al. 2012) or accurately predict (Hertzog et al. 2010) their abilities to learn and recall information later compared to younger individuals. However, longitudinal studies have generated more inconsistent results concerning the relationship of subjective and objective memory (Zelinski et al. 2001). Specifically, results vary between no concurrent change (Jungwirth et al. 2004; Taylor et al. 1992) and modest relationships (Gagnon et al. 1994; McDonald-Miszczak et al. 1995).

An explanation for the mixed findings may be that women and men differ in their ability to rate subjectively their memory performance. Indeed, some studies report women subjectively tend to rate their memory as worse than men (Gagnon et al. 1994), while other studies show no sex differences in subjective ratings (Bassett and Folstein 1993; Johansson et al. 1997). The accuracy of subjective ratings also yielded competing results when observing age, sex, and age by sex interactions. One study showed that older women's subjective memory was more accurate than younger women's memory as well as men's memory of all ages (Hertzog et al. 1990). Studies have also shown men to be overconfident when subjectively rating their memory abilities (i.e., they did not notice declines in objective memory, whereas women did; Dahl et al. 2009). Contrariwise, Perrig-Cheillo et al. (2000) found no differences in accuracy of subjective memory between men and women, despite the finding that men aged 75+performed better than younger men did. Both reports from Hertzog et al. (1990) and Perrig-Cheillo et al. (2000) suggest that both biological sexes advance their ability with age to accurately monitor changes in memory.

Additional covariates may also explain the mixed results in abilities to subjectively rate memory performance. For example, the previous literature has shown links between depressive symptoms and cognitive abilities (Montejo et al. 2014; Saczynski et al. 2010; Wilson et al. 2002). Furthermore, women report more depressive symptoms than men (Carayanni et al. 2012) and lower subjective ratings of memory (Burmester et al. 2016). However, results on the relationship between depressive symptoms and cognitive abilities are mixed. For instance, Neubauer et al. (2013) found no longitudinal link between depressive symptoms and cognitive abilities. Similarly, other covariates also show links to subjective ratings of memory, such as education, stress, and self-rated health (Montejo et al. 2014) although these too are subjected to inconsistent findings (Pedro et al. 2016).

Most of the studies that assessed subjective and objective memory have used a cross-sectional approach. While cross-sectional designs allow researchers to study age differences in abilities to monitor memory performance, they do not allow assessment of longitudinal correspondence between subjective and objective memory. In addition, the relationship in concurrent rates of change for subjective and objective memory has been found to be four times stronger compared to cross-sectional effects (Zimprich et al. 2003). When utilizing longitudinal data, findings suggest baseline complaints in subjective memory are associated with steeper declines in objective performance (Hohman et al. 2011; also see Reid and McLullich 2006). However, it should be noted that by comparing baseline predictors of subjective memory, comparisons of objective memory change are being made between individuals with and without complaints at baseline; thus, this approach does not capture intra-individual change in subjective memory. This is problematic given there is no way to assess if the changes in subjective memory correspond with changes in objective memory. Similarly, some longitudinal studies simply correlate change scores (last observation–first observation) between the two variables. While the provided information from these analytic techniques is valuable, current methods exist that address these methodological shortcomings. Specifically, utilizing methods that incorporate all measurement occasions grants the ability to assess differing trajectories (e.g., linear, quadratic) and account for random measurement error. In order to assess the necessary rates of change in subjective and objective memory, latent growth curve (LGC) modeling can be used. Johansson et al. (2004) used LGC to assess the longitudinal pattern and rates of change in the memory of the oldest old. Results indicated that objective memory performance declined with increasing age. Furthermore, LGC allowed for testing predictors in rates of change. For example, Johansson et al. (2004) found chronical age was negatively associated with initial levels in all memory tests (indicating older individuals scored lower on initial tests), but was not associated with slope (indicating declining rates in performance did not differ for individuals of different ages).

To estimate the relationship of change in subjective and objective memory, the current study will use a parallel process model incorporating LGC of both variables. We are aware of only two studies previously utilizing this approach to account for corresponding rates of memory change. Zimprich et al. (2003) found that changes in memory performance accounted for 25% of the variance observed in changes in subjective memory over a 4-year time period. Mascherek and Zimprich (2011) assessed the relationship of subjective and objective memory change and found similar results across a 12-year period. The parallel process model is preferable to other methods as it accounts for random measurement error and can explain why individuals differ in rates of change. However, Zimprich et al. (2003) and Mascherek and Zimprich (2011) did not find any difference based on initial levels of memory nor were any covariates included, such as age or depressive symptoms, which affect memory performance (e.g., Johansson et al. 2004; Rönnlund et al. 2005). Moreover, both models consisted of two or three measurement occasions, which do not allow for any assessment of different forms of change, such as linear or curvilinear trajectories. In order to test for these forms of change, at least four or more measurement occasions are needed.

The purpose of the current study is to assess the longitudinal correspondence of objective and subjective memory over an 8-year period in oldest-old individuals. The current study extends previous studies by using four measurement occasions of subjective and objective memory and by testing whether change in subjective and objective memory is best described by a linear or quadratic polynomial function. In addition, we also assess this correspondence separately for each sex using a multiple group analysis and the inclusion of time-varying depressive symptoms as a covariate. We hypothesize a correspondence of change in subjective and objective memory performance.

Method

Data were obtained from the Origins of Variance in the Oldest Old Study (OCTO; Johansson and Zarit 1995) and OCTO-Twin (McClearn et al. 1997) studies of oldest-old individuals. These two multidisciplinary population-based studies were conducted in Sweden and included three (OCTO) and four (OCTO-Twin) waves of data collection at 2-year intervals, resulting in 8 years of data and a total of 837 (539 females) participants. Due to twin pairs presenting a clustering concern, one individual was randomly selected from a twin pair. This random selection resulted in 330 individuals from the OCTO-Twin study. The final sample included 613 (403 females; 330 from OCTO-Twin; 283 from OCTO) individuals. All participants were over the age of 80 years with an average age of 85.25 years ($SD = 3.32$). OCTO recruited from the population registry of Jönköping municipality, and the OCTO-Twin study recruited participants from a national registry of multiple births in Sweden. Approximately 12% (OCTO-Twin) and 13% (OCTO) of the sample had completed data for all possible measurement occasions.

Measures

Objective memory

The first portion of the Memory-in-Reality Test was used to assess objective memory. For this portion, the participants are shown 10 common real-life objects. After a 30-min delay, participants are asked for free recall of the 10 objects they were shown. Scores are the number of correct recalls for the items (for details see Fiske and Gatz 2007).

Subjective memory

Subjective memory was assessed using the question, "Do you think on the whole, your memory is good or poor?" Participants could then rate their memory on a seven-point scale from "very poor" to "very good." High scores indicate better ratings of memory.

Depressive symptoms

Depressive symptoms were assessed with the short form of the Center for Epidemiological Studies Depression Scale (CES-D, Kohout et al. 1993; Radloff 1977; Radloff and Teri 1986). The short form consists of 11 items in which participants are asked about the frequency of which they experienced the symptoms. Ratings for each item use a 4-point scale from (0) "rarely or none of the time" to (3) "most or all of the time." Total depressive symptoms were calculated by summing all of the items, with higher number indicating more depressive symptoms.

Statistical analyses

First, separate LGC analyses were conducted for objective and subjective memory to assess differences in baseline levels and rates of changes for both gender (males and females). The LGC models estimated an intercept (level) parameter reflecting where individuals start on average for the first measurement occasion. In addition, each LGC models estimated a slope parameter reflecting the average rate of linear change. Both intercept and slope parameters are characterized by a mean and variance. There is also a covariance between them. In addition, a quadratic growth component was added to test whether a quadratic function better describes the change of subjective and objective memory. Using the best fitting growth curve model, age at the first measurement occasion was added into the model as a predictor for the growth curve factors. Assessment of equality in growth parameters was tested by comparing models where growth parameters were set equal between genders and models where they were allowed to be estimate freely.

In order to assess the longitudinal correspondence between objective and subjective memory, a parallel process was conducted where the latent growth factors for subjective memory were regressed onto the latent growth factors for objective memory. Specifically, the intercept parameter for subjective memory was regressed onto the intercept parameter of objective memory. Moreover, the slope parameter of subjective memory was regressed onto both the intercept and slope parameters of objective memory. As in the individual LGCs, age at baseline was added as a predictor for both intercept and slope parameters. Again, to assess the equality of growth and regression parameters, models were compared by setting estimates to be equal across groups.

Age and depressive symptoms were included in the model to control for possible confounding effects. In the case of age, a time-invariant covariate (i.e., the measures do not change from one measurement to the next within the same persons), growth factors were regressed onto the time invariant to control for its effects. In the case of depressive symptoms, a time-varying predictor, the indicators for memory were regressed onto its corresponding measurement of the covariate (see Fig. 1).

The software program Mplus and Full Information Maximum Likelihood (FIML) were used to estimate all models. For model fit criteria, we used the root mean square error of approximation (RMSEA), Akaike information criterion (AIC), comparative fit index (CIF), and χ^2 tests of model fit. When assessing equality in growth parameters between males and females, a χ^2 difference test was used. A significant difference indicates that the equality constraint does not hold across groups.

Results

Preliminary analyses

Means, standard deviations, and correlations among the study variables are presented in Table 1. Correlations between objective and subjective memory range from −.337 to .530 for males and from −.089 to .435 for females. As can be seen, later scores (wave 3 and 4) of objective and subjective memory did not correlate with each other for males. For females, a significant correlation was observed at wave 3 between both memory measures.

Latent growth curve analyses

Separate LGC were analyzed for objective and subjective memory. The model implying linear growth showed a good fit for both measures of memory and sex (see Table 2). For both memory measures, a quadratic growth component was added. However, the quadratic slope estimate was not significant and did not improve the fit of the models for either measurement of memory or sex. Adding age as a predictor for the intercept and slope parameter improved model fit and also showed significant effects on certain growth parameters. Females significantly declined in both objective and

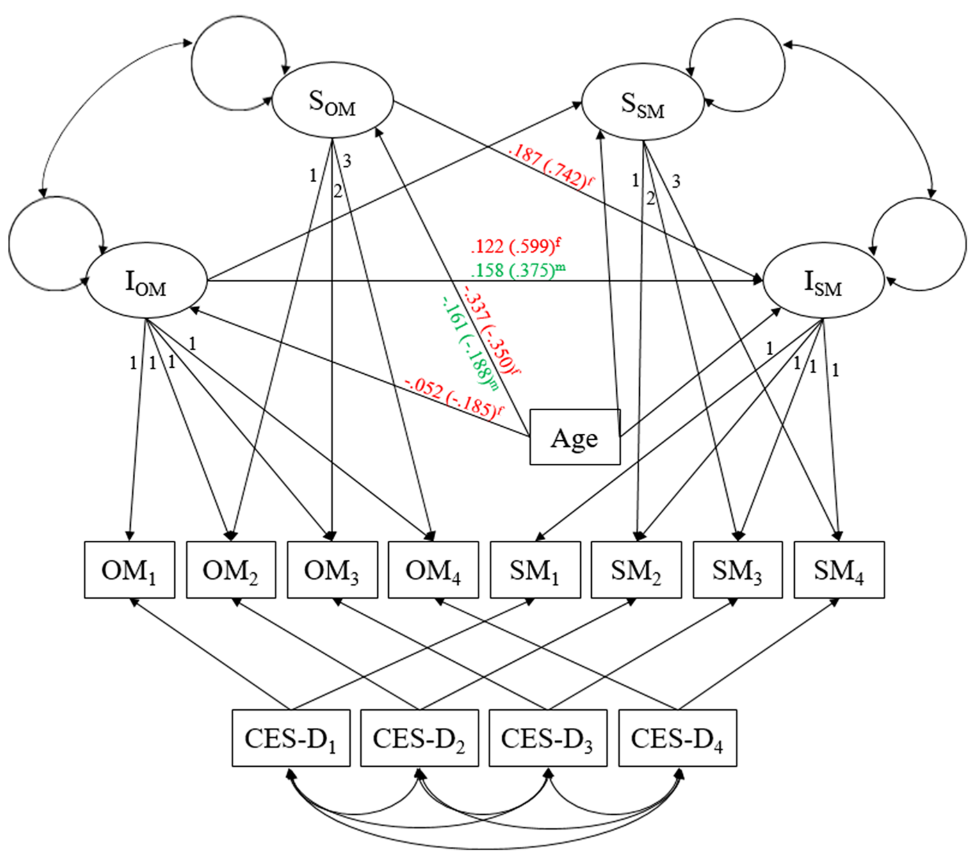

Fig. 1 Structural equation model for the parallel process and regression weights. *I* with subscript denotes intercept factor, *S* with subscript denotes slope factor. *OM* objective memory, *SM* subjective memory, *CES-D* Center for Epidemiologic Studies Depression Scale. Labels show only significant regression estimates. Estimates for females are followed by a superscript *f*, and estimates for males are followed by a superscript *m*. Standardized regression weights are in parentheses

Table 1 Correlations and descriptive statistics for study variables

	RC_1	RC_2	RC_3	RC_4	SM_1	SM_2	SM_3	SM_4
RC_1	–	.797**	.682**	.610**	.294**	.138	.185*	.045
RC_2	.770**	–	.811**	.708**	.315**	.149*	.156	.048
RC_3	.731**	.719**	–	.884**	.263**	.299**	.170	.114
RC_4	.504**	.605**	.745**	–	.172	.258*	−.089	.154
RC_5	−.032	.256	.384	.256	.129	.435*	.099	.222
SM_1	.252**	.218*	.287*	.279	–	.346**	.323**	.312**
SM_2	.136	.198	.266*	.530**	.478**	–	.375**	.503**
SM_3	.185	.202	−.027	−.030	.256*	.301*	–	.547**
SM_4	.004	.150	−.142	.121	.276	.185	.427*	–
SM_5	−.482	−.008	−.337	.075	.618*	.387	.657**	.394
Means								
Females	4.59	4.23	4.07	4.41	5.08	4.96	4.83	4.90
Males	4.68	4.50	4.58	4.54	4.81	4.90	4.77	4.58
SD								
Females	3.43	3.46	3.45	3.81	1.27	1.38	1.51	1.50
Males	3.05	2.92	3.21	3.37	1.58	1.43	1.51	1.62

Correlations above the diagonal are for Females and below the diagonal are for males. Subscripts indicate the measurement occasion

RC recall, *SM* subjective memory, *SD* standard deviation

*$p < .05$; **$p < .01$ (two-tailed)

Table 2 Model fit estimates for separate growth curves with age and depressive symptoms included as covariates

Model	Objective memory				Subjective memory			
	AIC	CFI	RMSEA [90% CI]	χ^2 (*df*)	AIC	CFI	RMSEA [90% CI]	χ^2 (*df*)
No constraints	235.122	.943	.048 [.037, .060]	111.122 (46)	232.872	.883	.047 [.036, .059]	108.872 (46)
Intercept constraint	235.064	.943	.048 [.037, .059]	113.064 (47)	233.538	.880	.047 [.036, .059]	111.538 (47)
Slope constraint	2.33.174	.943	.048 [.036, .059]	111.174 (47)	231.789	.883	.047 [.036, .058]	109.789 (47)

AIC Akaike information criteria, *CFI* comparative fit index, *RMSEA* root mean square error of approximation, *CI* confidence interval, *df* degrees of freedom

subjective memory, and older females had lower initial recall scores and declined faster than their younger counterparts. However, the insignificant effect of age on the slope parameter showed that older females had lower initial subjective ratings but declined at similar rates to their younger counterparts (see Fig. 2). For males, only a significant effect was observed for the intercept parameter in objective memory meaning that older males had lower initial levels of objective memory but declined at a similar rate as their younger counterparts. However, age did not have a significant effect on either growth parameter for subjective memory indicating a similar trajectory for all males (see Fig. 3). Table 3 shows the estimates and standard errors of the single-variable models. Model comparisons where either the intercept or slope was constrained to be equal between biological sexes were assessed via a χ^2 difference test. Neither the intercept nor slopes were statistically different between males and females ($\Delta\chi^2$ (1) = 0.1635 $p = .163$, $\Delta\chi^2$ (1) = 0.052 $p = .820$, for intercept and slope, respectively).

Next, the parallel process model with objective memory predicting subjective memory for males and females was tested retaining age as a predictor of the growth parameters. Figure 3 shows a path diagram for this model with significant regression estimates. Model fit for this model was good (CFI = .940, RMSEA = .036, 90% CI = [.027, .044], AIC = 394.960, χ^2 (102) = 182.960, $p < .001$). Table 4 displays the growth parameter estimates and age effects for the parallel model by sex. Results for objective memory showed a lower initial performance for older individuals. This effect was significantly greater in females than males

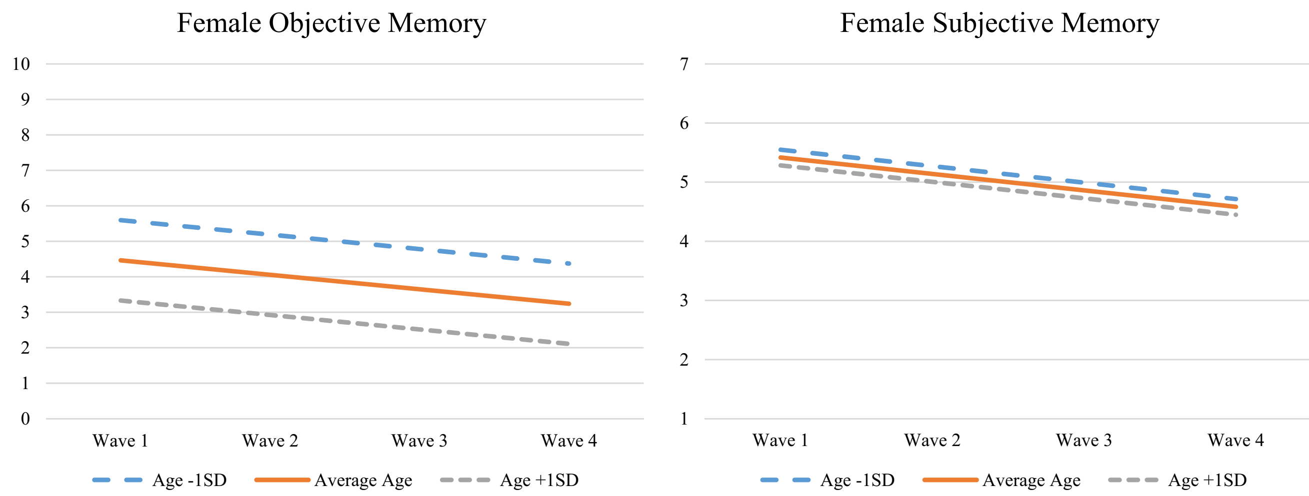

Fig. 2 Plots for objective and subjective memory for females by age

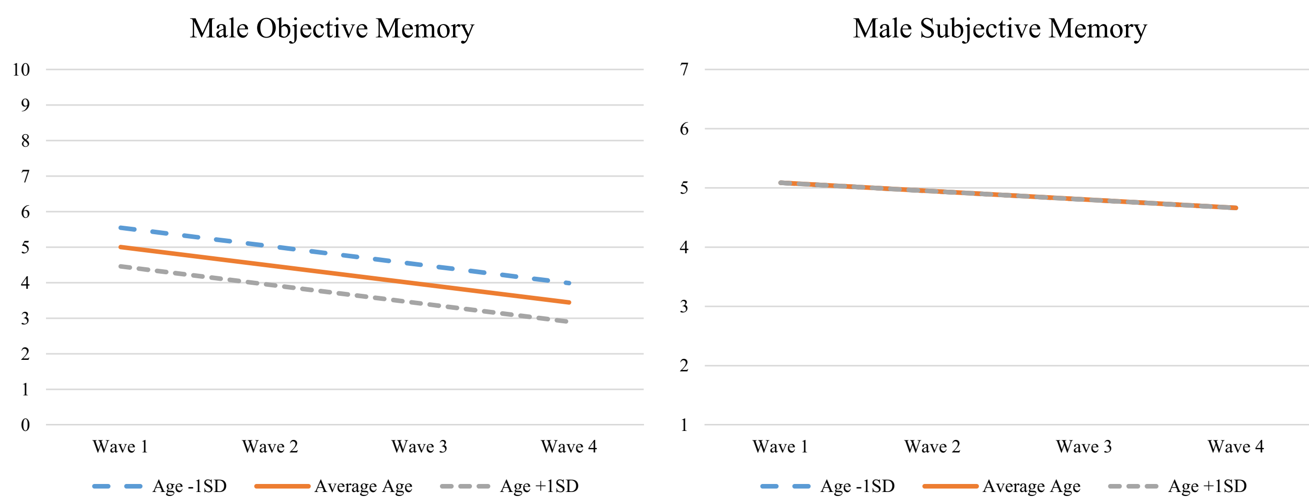

Fig. 3 Plots for objective and subjective memory for males by age

Table 3 Growth parameter estimates from single-variable growth models with age and depressive symptoms as covariates

Gender	Objective memory				Subjective memory			
	Intercept	Age on intercept	Slope	Age on slope	Intercept	Age on intercept	Slope	Age on slope
Females	4.462*** (.241)	−.342*** (.051)	−.569*** (.127)	−.049* (.024)	5.4.16*** (.099)	−.040* (.018)	−.278*** (.071)	.008 (.014)
Males	5.003*** (.288)	−.164* (.066)	−.519** (.173)	.036 (.036)	5.086*** (.163)	.029 (.034)	−.141 (.116)	−.019 (.024)

Standard errors are in parentheses

*$p<.05$; **$p<.01$; ***$p<.001$ (two-tailed)

($\Delta\chi^2$ (1) = 4.121 $p=.042$), indicating older females showed a larger difference from their younger counterpart compared to males. Slope parameters were statistically significant for both males and females, indicating a significant decrease in objective memory. However, the effect of age onto the slope parameter was only significant in females, with older

Table 4 Growth parameter estimates from parallel process model with age as predictor and depression as time-varying covariate

Estimate	Objective memory				Subjective memory			
	Intercept	Age on intercept	Slope	Age on slope	Intercept	Age on intercept	Slope	Age on slope
Females	4.457*** (.241)	−.337*** (.051)	−.579** (.128)	−.052* (.025)	4.784*** (.142)	−.008 (.019)	−.098 (.106)	.016 (.015)
Males	4.937*** (.286)	−.161* (.066)	−.445** (.170)	.050 (.035)	4.253*** (.289)	.049 (.034)	.017 (.201)	−.020 (.025)

Standard errors are in parentheses

*$p<.05$; **$p<.01$; ***$p<.001$ (two-tailed)

females declining faster than their younger counterparts. Model comparisons showed that there was no difference in either the objective memory intercept or slope parameters between males and females ($\Delta\chi^2$ (1) = 1.519, $p = .218$, and $\Delta\chi^2$ (1) = 0.379, $p = .538$, respectively).

For subjective memory, slope estimates were not significant for either gender nor did age have any effect. However, in order to assess the concurrent rates of change in objective and subjective memory, the parallel process regressed the subjective memory growth factor onto the objective memory growth factors. The direct effects between the growth curve factors did differ between genders. The intercept factor for objective memory had a positive effect on the subjective memory intercept factor for both males and females, but had no effect on the slope parameter. However, these effects were not significantly different from one another ($\Delta\chi^2$ (1) = 0.39, $p = .532$ for subjective memory intercept on objective memory intercept and $\Delta\chi^2$ (1) = 0.154, $p = .694$ for subjective memory slope on objective memory intercept). That is, those with better scores on objective memory tests at baseline still had higher ratings of subjective memory. However, these scores had no influence on the change observed in subjective ratings, and these effects did not differ between males and females. Lastly, the objective memory slope showed a positive effect on the subjective memory slope for females only. A greater decline in objective memory was also accompanied with a more pronounced decline in subjective memory. As noted earlier, the age effect on the objective memory slope showed older individuals at the start of the study declined faster. This means that older females in the study showed concurrent decreases in subjective memory. Given that males did not have a significant association between the two slope estimates, there appeared to be no concurrent change in subjective memory. Figure 4 shows the trajectories of subjective memory when accounting for changes in objective memory through the parallel process model. Refer back to Fig. 3 for the parallel process model with significant regression coefficients.

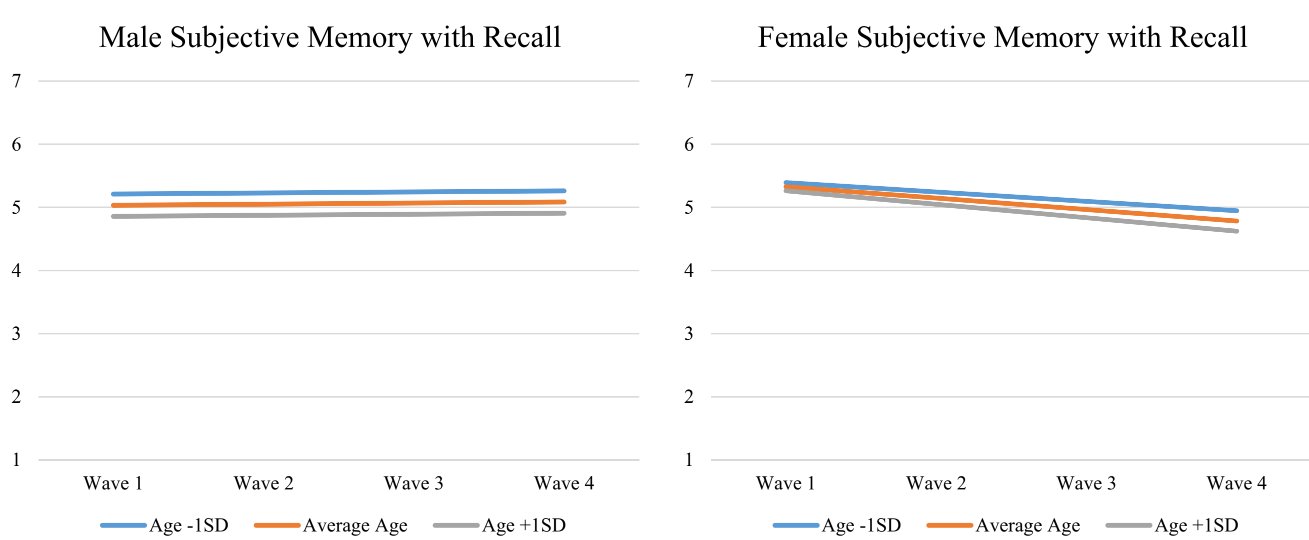

Fig. 4 Plots for subjective memory when accounting for objective memory by gender and age

Discussion

The present study examined the longitudinal correspondence of objective and subjective memory using data from two major Swedish population-based studies on individuals aged 80 and older. First, our results indicated that both males and females decline in average at similar rates in objective memory, yet only females show declines in subjective memory. Notably, the results from the parallel process model yielded a significant effect between changes in objective memory and changes in subjective memory in females, but not in males. This finding indicates that females seem to have a better metacognitive ability to monitor changes in their own memory performance. As a result, objective performance tasks are more informative over self-report measure in males as they seem to be less accurate in recognizing or reporting own memory changes.

These results coincide with the previous research. Trajectories found in objective memory are similar to the results found by Johansson et al. (2004). This is not surprising given part of the OCTO-Twin data in the present study was also used by Johansson et al. (2004). However, the present study utilized a different memory test for objective memory. This may explain why differences in slope parameters were not found between biological sexes. In addition, age at baseline only effected the intercept parameters, and this effect was larger in females.

Trajectories of subjective memory painted a different picture. For males, a nonsignificant slope was observed showing no average change in subjective memory over time. In addition, no effect of age was found for males on either growth parameter. On the other hand, a significant negative slope was found for females as well as an effect of age on initial levels. These differences suggest a better metacognitive ability in females in recognizing objective changes. Moreover, our findings matched previous findings that older female subjective memory was more accurate than males (Hertzog et al. 1990) and older males are over confident when subjectively rating their memory (Dahl et al. 2009). However, this is contradictory to Perrig-Cheillo et al. (2000) where males 75 + performed on average better than younger men. Furthermore, the parallel process model corroborated a gender difference in subjective memory where the objective memory slope had an effect on the subjective memory slope for females only.

The parallel process model highlights that metacognitive ability in females is retained with age in the oldest-old individuals. That is, women who were older at baseline had more negative, or steeper, subjective memory trajectories. Graphical representation of the parallel process model highlights this maintained ability with advancing age. This is congruent to previous findings indicating increases in the ability to monitor memory changes with advancing age (Hertzog et al. 1990).

The current findings contribute to the literature by expanding on the two previous models utilizing parallel processes (Mascherek and Zimprich 2011; Zimprich et al. 2003) and added age as a predictor to the parallel process. The multiple group design allowed the simultaneous assessment of memory correspondence between males and females, and by age while controlling for depressive symptoms as a time-varying covariate. These additions highlighted interesting findings that both corroborated and contradicted previous literature. Thusly, our results highlight the need for replications of memory correspondence utilizing the parallel process model.

The large sample size, the longitudinal design, and the parallel process model are all strengths of the current study. However, there are also some limitations. One is the potential for measurement error in the subjective memory question. Despite the commonality of its use and its predictive validity, it is possible that individuals were comparing their memory to societal expectations instead of actual change in their memory (i.e., my memory is good and good enough for being 80 years old). In addition, the parallel process model is somewhat complex. When incorporating additional covariates, convergence issues are likely. For instance, educational attainment and self-rated health were added into both the single-variable growth curve and parallel process models, yet no convergence was obtained. This was also found when the variables were included as the only additional covariates. Moreover, the likelihood of this issue increases when additional time-varying covariates are included into the model. However, the ability to address this complex process controlling for additional factors is limited to model performance. Nonetheless, future researchers should still attempt these analyses whenever possible. In the current study, we utilized participants from population-based studies in Sweden. Previous research has shown that these data are representative of health and bio-behavioral functioning in Swedish older adults (Simmons et al. 1997). However, examining culture specific or cultural differences was beyond the scope of this project. Still, future research should apply similar models to other population-based studies to examine possible culture effects. The current study used measurement occasion as the time metric. Future research might consider different time metrics (Fauth et al. 2014). The time metric could be modeled by chronological age or time-to-events or time-from-events. However, these time models require many more participants as it can generate increased missing data. Moreover, changing the model of time can become very complex, resulting in as many indicators as the range for age, leading to convergence issues. In addition, future research might assess heterogeneity of the sample. Given the significant amount of variance in the growth parameters, unobserved sub-groups may exist.

In conclusion, the present study assessed the longitudinal correspondence between objective and subjective memory in the oldest old. Results showed that both genders declined in objective memory with advancing age. However, only women showed declines in subjective memory. The use of a parallel process model corroborated this difference as women showed better metacognitive abilities to monitor changes in objective memory. This ability also increased in the older females of the sample. When assessing changes in memory in the oldest-old individuals, objective performance measures are more informative for males, as their subjective assessments do not coincide with actual changes in memory performance. Furthermore, subjective assessments should also be used with caution in the oldest-old female population.

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