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## Gender differences in cognitive performance in old age: Adjusting for longevity

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| **Corresponding Author:** | Marcus Praetorius, M.D.<br>University of Gothenburg<br>Gothenburg, SWEDEN |
| **Corresponding Author Secondary Information:** | |
| **Corresponding Author's Institution:** | University of Gothenburg |
| **Corresponding Author's Secondary Institution:** | |
| **First Author:** | Marcus Praetorius, M.D. |
| **First Author Secondary Information:** | |
| **Order of Authors:** | Marcus Praetorius, M.D. |
| | Valgeir Thorvaldsson, Ph.D |
| | Boo Johansson, Ph.D. |
| | Linda Hassing, Ph.D |
| **Order of Authors Secondary Information:** | |
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# Gender differences in cognitive performance in old age: Adjusting for longevity

Marcus Praetorius*, Valgeir Thorvaldsson, Boo Johansson, Linda B. Hassing

Department of Psychology, University of Gothenburg, Sweden

**Corresponding author:* Marcus Praetorius, MD, Department of Psychology, University of Gothenburg, Box 500, SE-405 30 Gothenburg, Sweden, +46 31 786-1646 (voice), E-mail: Marcus.Praetorius@psy.gu.se

Objective: To examine gender differences in level and change of cognitive performance in the oldest old while accounting for gender differences in longevity.

Method: 574 individuals, aged 80 years and older, from the OCTO-twin study. Five cognitive domains were administered at 5 occasions at 2-year intervals.

Results: There were no differences between men and women in cognition with the exception that men showed a steeper rate of decline in semantic memory. This effect was driven by men who developed dementia and declined at a faster rate than women.

Conclusion: Our results support previous findings showing minor to non-existing gender differences in cognition among non-demented individuals in very old age when taking gender differences in longevity into account.

Previous studies on gender differences in cognitive performance typically support two conclusive differences. Women generally outperform men in episodic memory (Herlitz, Nilsson, & Bäckman, 1997; Herlitz & Rehnman, 2008) while men perform better in spatial tasks (Lewin, Wolgers, & Herlitz, 2001; Lövden et al., 2007). The differences in mean levels are, however, relatively small for both spatial ability ($d$ = 0.45; Hyde, 1981) and episodic memory ($d$ = 0.25 - 0.53; Herlitz & Rehnman, 2008). These differences appear to be stable across the life span (Aartsen, Martin, & Zimprich, 2004; de Frias, Nilsson, & Herlitz, 2006; Finkel, Reynolds, Berg, & Pedersen, 2003; Finkel, Reynolds, McArdle, Gatz, & Pedersen, 2006) and are apparent also in very old ages (Read et al., 2006). Studies also indicate gender differences in mean level in general knowledge favoring men among younger age cohorts (Lynn & Irwing, 2002; Lynn, Ivanec, & Zarevski, 2009), although this is not fully supported across the adult life span (Maitland, Herlitz, Nyberg, Backman, & Nilsson, 2004).

Cognitive function declines in normal aging, moreover, it has been demonstrated that decline in cognitive function is related to time to death, i.e. terminal decline (Kleemeier, 1962). The terminal cognitive decline hypothesis (Kleemeier, 1962; Riegel & Riegel, 1972) assumes that decline in cognitive functioning accelerates some number of years prior to death. Several studies have confirmed that terminal decline trajectories are related to impending death (Johansson et al., 2004; Piccinin, Muniz, Matthews, & Johansson, 2011; Thorvaldsson, Hofer, & Johansson, 2006). The decline in cognition is most pronounced in domains requiring more mental resources, such as perceptual speed. The impact of terminal decline varies across both cognitive domains and studies. For example, a sharp accelerated decline was found across the cognitive domains of semantic memory, episodic memory, working memory and perceptual speed 2.5 years prior to death in a study by Wilson, Segawa, Hizel, Boyle, & Bennett (2012), while another study found an accelerated decline 6.5 years to nearly 15 years before death depending on cognitive domain (Verbal ability, Spatial ability and Perceptual speed: Thorvaldsson et al., 2008).

Given that time to death is an important factor in understanding cognitive aging it is of theoretical interest to examine if time to death has an impact on the observed differences between men and women in cognitive performance. Typically, adjustments are made for differences in age and education. However, it has not been tested if differences in time to death affect the gender differences seen in cognition. According to the terminal decline hypothesis we could expect gender differences in cognitive performance to be related to differences in longevity. In present study we control for differences in longevity when examining gender differences in cognitive function. When we control for the female longer survival, we expect earlier confirmed female advantage in episodic memory to be reduced. We also expect the male advantage in spatial ability and semantic memory to be more pronounced when controlling for men's shorter survival.

## Method

### *Participants*

Data was drawn from the OCTO Twin Study (McClearn et al., 1997), including a Swedish population-based twin sample, aged 80 years and older, born in 1893-1913, where both twins were alive at inclusion (N = 702 individuals/351 pairs). Participants were examined five times at two year intervals in between 1991-2002. All examinations were conducted by registered nurses in the participant's place of residency with a broad based behavioral test battery. Test sessions took 3.5 - 4 hours, including rest periods. Dementia diagnoses were considered in accordance with DSM-III-R criteria for dementia (American Psychiatric Association, 1987). All suspected dementia cases were taken to a consensus conference with a physician, nurse and neuropsychologist. Individuals with dementia at first measurement occasion were excluded ($n$ = 108) as well as 20 individuals with unknown datum of death. Information about time of death was obtained from the Swedish Census Register. After exclusion 574 individuals remained in the sample for analyses (see Table 1 for background characteristics).

Table 1.

*Cognitive measures*

Ten tests were used to measure cognitive performance; the tests represent semantic memory, episodic memory, short-term ability, spatial ability and motor- and perceptual speed. We constructed factor scores for these five domains using regression scores of each factor at each measurement. All cognitive domains were thereafter transformed to a $T$ distribution with $M$ = 50 and $SD$ = 10.

*Semantic memory:* The Information test measures general knowledge and is a modified version (Jonson & Molander, 1964) of the Wechsler Adult Intelligence Scale, WAIS (Wechsler, 1981). Maximum score is 44 points. The Synonyms test requires the participant to find a synonym to match a target word; the task taps knowledge of verbal ability and is a part of the Dureman-Sälde battery (Dureman & Sälde, 1959).

*Episodic memory.* Memory-in-Reality (MIR) Test first requires the naming of 10 common real-life objects shown to the subject. The subjects are then instructed to place these objects in the different rooms of a three-dimensional model of an apartment, according to their own preferences. Thirty minutes later they are asked to recall the objects followed by a recognition task for the objects not recalled. Subjects are then asked to place the objects in the same locations as they did previously - the relocation test. The maximum score in each subtest is 10 (Johansson, 1988/1989). The present study only uses the recall subtest. Prose Recall is a

Swedish prose recall task similar to the prose passages in the Wechsler Memory Test (WMS) (Wechsler, 1945). To maintain attention during presentation of the story, it was designed to be brief (100 words) and to have a humorous point. Subjects are asked to recall the story after presentation. Responses are coded for the amount of information recalled in a manner similar to the WMS. The maximum score is 16. Thurstone's Picture Memory is a nonverbal, long-term memory test (Thurstone & Thurstone, 1949). Subjects are shown 28 pictures and then asked for recognition of these among others distractors. The pictures were enlarged from the original version to minimize any possible visual problems. The maximum score is 28.

*Short-term memory:* The Digit Span Test measures short-term memory and working memory for orally presented digits (Wechsler, 1991). In the forward part, subjects are asked to recall the digits in the same order as they were presented, whereas in the backward part, they are instructed to recall the digits in reverse order. The maximum score is 9 for the forward, and 8 for the backward part of the test.

*Spatial ability*: Block Design requires reproduction of a pattern shown on a set of cards using red and white blocks and has a maximum score of 42 (Dureman & Sälde, 1959). The Figure Logic task requires the person to identify one figure out of five in a row that is different in concept from the rest. Maximum score is 30 (Dureman & Sälde, 1959).

*Motor- and perceptual speed:* A modified version of the speeded Digit–Symbol Substitution Test (Wechsler, 1991) was used which measures motor speed and accuracy. The participant is given a list of symbols associated with digits from 1 to 9 and is asked to fill in the blanks with the symbols that correspond to each number. The test score is the total number of correct sequential matching of digits to symbols in a 90 seconds interval.

*Statistical analyses*

We analyzed individual differences in levels and rates of linear and quadratic change in cognitive performance using three level multilevel models (i.e., growth curve models) with repeated measure (i.e., time) nested within individuals nested within twin-pair (i.e. included in the models as random effects, these effects are not shown in Table 2 and 3). We specified the time factors as one year linear effects of "time to death" and centered intercepts at two years prior to death. The reason for centering the slope two years prior to death and not at the actual time of death was because it would not be possible to obtain performance score at this point. The slope was coded using negative values counting down to death. To exemplify, if a participant was examined at 10, 8, 6, 4 and 2 years before death the centered slope was coded as -8, -6, -4, -2 and 0. Age at first measurement occasion, education, and incident dementia were specified as level 2 covariates (i.e. fixed effects) and grand mean centered. Individuals who remained non-demented over the study period and men were coded as reference values. All models were fitted in IBM SPSS Statistics 22 using full information maximum likelihood parameter estimation.

## Results

Comparison between background characteristics between men and women showed that men generally had a longer education and an earlier age at onset of dementia than the women while the women had a longer life expectancy in comparison to the men (see Table 1). There were no other significant gender differences among covariates included in the analyses.

The analyses comparing men and women in cognitive function, adjusting for differences in time to death reflect no significant gender differences in level of performance (see Table 2). Men showed however an 82 % steeper linear terminal decline in semantic memory than women (see Table 2 and Figure 1). To further explore the gender differences in semantic memory we included an interaction term of incident dementia and gender at level of performance and linear semantic memory change. This resulted in a non-significant effect of gender on linear change (see Table 3). There was a significant main effect of incident dementia on level of performance and linear semantic memory change. There was also a significant interaction effect between gender and incident dementia for linear rate of change in semantic memory. Figure 2 demonstrate that there were no significant gender differences among individuals who remained non-demented over the study period. Among individuals who developed dementia over the study period, men showed a steeper terminal decline.

## Discussion

The present study aimed to examine gender differences in level of cognitive performance and change in late life, taking into account differential life expectancy between the genders. We fitted hierarchical linear models with specification of time as time to death, controlling for age at study entry, education and incident dementia.

We expected that by adjusting for gender differences in time to death we would cancel out gender differences in episodic memory and observe more pronounced differences in semantic memory and spatial ability. In general, we found no gender differences in the cognitive tasks. More specific, our findings of no gender differences in episodic memory between men and women supported our hypothesis that controlling for differences in longevity resulted in decreased female advantage in episodic memory.  However, we found no evidence for stronger male advantage in semantic memory and spatial ability when controlling for longevity as predicted. Our results indicated, on the contrary, a steeper linear decline in semantic memory among men. When exploring this effect further we found that the steeper decline among men was related to incident dementia such that men who developed dementia declined steeper than women. This might be explained by the fact that men developed dementia at an earlier age than women.

Although gender differences are seen in some cognitive domains at younger ages and early old age, it seems that these differences are not very pronounced among the oldest old, and especially not when gender differences in life expectancy are taken into account, as our findings indicate. Whatever factors that may explain gender differences seen in cognition at younger ages; it seems that these differences are overshadowed by other conditions or mechanisms in very old age, most likely to be related to age-related morbidity and possibly Alzheimer´s neuropathology (e.g. tau and amyloid loads).

Some of the strengths in our study are that we used a population-based sample, screened for dementia at every test occasion, and a broad test battery encompassing assessments across several cognitive domains, including semantic memory (general knowledge and verbal ability), episodic memory (picture, prose and object recall), short-term and working memory and spatial abilities (visuo-spatial ability and reasoning). The major strength, however, is related to the study design which allows us to estimate change across five measurement occasions, ranging across 8 years, were the majority of the sample was followed until death, applying analyses of inter-individual differences in intra-individual change.

In sum, there is an overall lack of gender differences in cognitive performance and change in later life among non-demented men and women when taking gender differences in longevity into account. Therefore, we conclude that men and women are cognitively more alike than unlike, in very old age.

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Table 1.

*Background Characteristics of the OCTO-Twin Sample (N=574)*

| Variables | Men | Women | *p* |
|---|---|---|---|
| Education *M* (*SD*) | 7.51 (2.9) | 7.02 (1.9) | .031 |
| Age at baseline *M* (*SD*) | 83.15 (2.9) | 83.66 (3.2) | .056 |
| Age at death *M* (*SD*) | 89.25 (4.0) | 90.75 (4.9) | <.001 |
| Age at onset of dementia *M* (*SD*) | 86.35 (3.3) | 87.63 (3.4) | .046 |
| Incident dementia cases over study period % | 27.5 | 29.2 | .68 |

Table 2.

*Estimated Gender Differences in Level and Rate of Linear Change in Cognitive Performance*

| Cognitive domains | Estimate | *p* | 95% CI |
|---|---|---|---|
| Semantic memory | | | |
| Average performance 2 years prior to death[a] | 50.31 | <.001 | 48.74, 51.88 |
| Females | -0.80 | .41 | -2.69, 1.10 |
| Average linear change[b] | -0.44 | <.001 | -0.69, -0.20 |
| Females | 0.36 | .017 | 0.07, 0.66 |
| Average accelerated change[c] | - | - | - |
| Females | - | - | - |
| Episodic memory | | | |
| Average performance 2 years prior to death | 48.94 | <.001 | 47.29, 50.59 |
| Females | 1.52 | .12 | -0.39, 3.44 |
| Average linear change | -0.77 | .003 | -1.28, -0.26 |
| Females | 0.02 | .94 | -0.59, 0.64 |
| Average accelerated change | -0.07 | .012 | -0.12, -0.02 |
| Females | 0.01 | .80 | -0.05, 0.07 |
| Short-term memory | | | |
| Average performance 2 years prior to death | 49.08 | <.001 | 47.59, 50.56 |
| Females | 0.89 | .33 | -0.89, 2.68 |
| Average linear change | -0.43 | .003 | -0.71, -0.15 |
| Females | 0.21 | .22 | -0.12, 0.54 |
| Average accelerated change | - | - | - |
| Females | - | - | - |
| Spatial ability | | | |

| | | | |
|---|---|---|---|
| Average performance 2 years prior to death | 48.80 | <.001 | 47.19, 50.41 |
| Females | -0.25 | .80 | -2.19, 1.70 |
| Average linear change | -0.87 | <.001 | -1.33, -0.40 |
| Females | -0.28 | .34 | -0.85, 0.29 |
| Average accelerated change | -0.06 | .008 | -0.11, -0.02 |
| Females | -0.02 | .41 | -0.08, 0.03 |
| Motor- and perceptual speed | | | |
| Average performance 2 years prior to death | 48.83 | <.001 | 47.48, 50.18 |
| Females | 0.17 | .84 | -1.45, 1.79 |
| Average linear change | -0.73 | <.001 | -1.12, -0.34 |
| Females | -0.08 | .73 | -0.57, 0.41 |
| Average accelerated change | -0.04 | .049 | -0.09, -0.01 |
| Females | -0.01 | .65 | -0.06, 0.04 |

Note: Age at baseline, education and incident dementia are included as fixed level 2 covariates in to the models. [a]*Average performance 2 years prior to death* = Intercept; [b]*Average linear change* = Linear change; [c]*Average accelerated change* = Quadratic change.

Table 3.

*Estimated Gender Differences in Level and Rate of Linear Semantic Memory Change when Adjusting for Incident Dementia*

| Cognitive domains | Estimate | *p* | 95% CI |
|---|---|---|---|
| Sematic memory | | | |
| Average performance 2 years prior to death[a] | 51.25 | <.001 | 49.62, 52.88 |
| Female | -1.01 | .33 | -3.06, 1.03 |
| Incident dementia case | -11.59 | <.001 | -14.42, -8.75 |
| Gender x Incident dementia | 0.33 | .86 | -3.38, 4.00 |
| Average linear change[b] | 0.01 | .93 | -0.24, 0.26 |
| Female | 0.12 | .43 | -0.18, 0.42 |
| Incident dementia case | -1.88 | <.001 | -2.39, -1.37 |
| Gender x Incident dementia | 0.94 | .004 | 0.31, 1.57 |

*Note:* Age at baseline, education and incident dementia are included as fixed level 2 covariates in to the model. . [a]*Average performance 2 years prior to death* = Intercept; [b]*Average linear change* = Linear change.

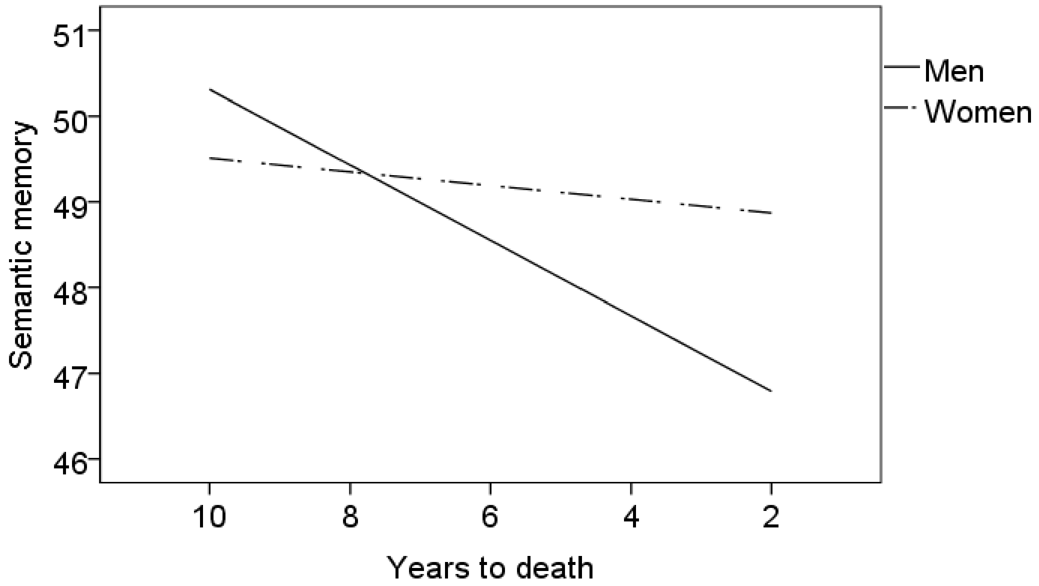


Figure 1. Gender differences in average linear change per year prior to death in semantic memory.

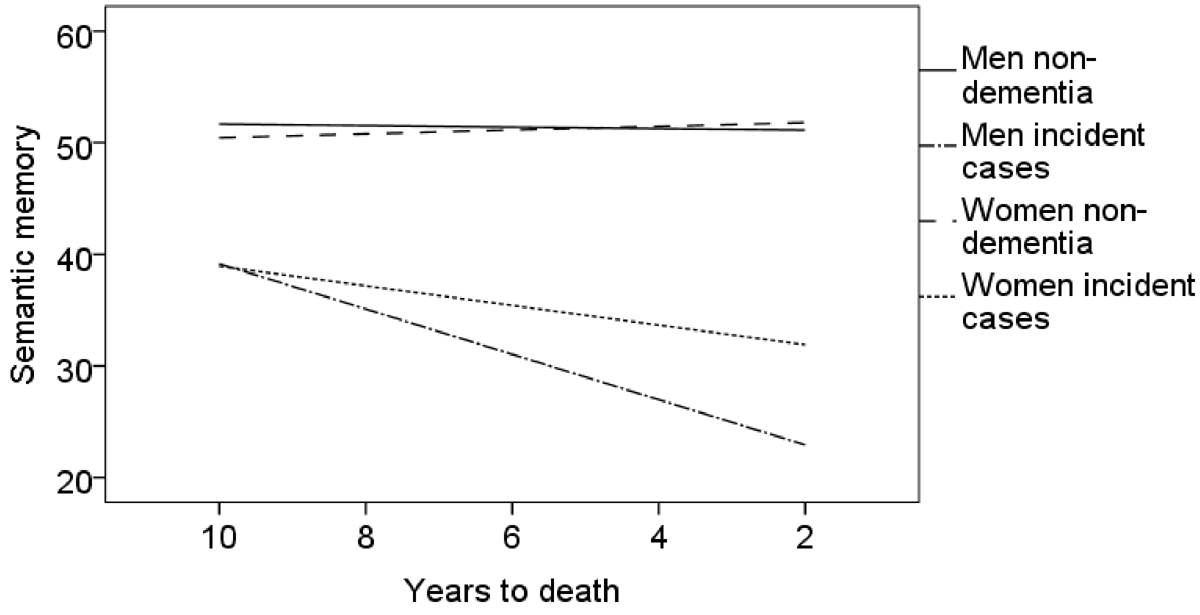


Figure 2. Average linear change per year prior to death in semantic memory among non-demented and subsequent demented men and women.