Spousal loss and change in cognitive functioning:

An examination of temporal patterns and gender differences

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Abstract

Objectives: The study investigates whether the disadvantaged position of men in the adverse consequences of widowhood for health and mortality also exists for changes in cognitive health.

Methods: We used data of up to 1,269 men and women aged 65 years and older who participated in the Longitudinal Aging Study Amsterdam in three-yearly assessments between 1992 and 2012 (5,123 person-observations). All were married and without cognitive impairment (MMSE ≥ 24) at baseline and up to 419 lost their spouse. In fixed-effects regression models, the effect of spousal loss on change in four domains of cognitive functioning was estimated independently of age-related cognitive change.

Results: For women, a robust temporary decrease was found in the second year after spousal loss in the reasoning domain, but not in global cognitive functioning, processing speed, or memory. No robust effects were found for men.

Discussion: Considering that only one cognitive domain was affected and effects were temporary, cognitive functioning seems rather robust to the experience of spousal loss. Despite men having often been reported to be in a disadvantaged position in other health domains, our analyses indicate no such pattern for cognitive functioning.

Keywords: ageing, cognitive decline, widowhood, bereavement

1 Introduction and Background

Losing the spouse is a stressful but common experience at higher ages. It is associated with depressive symptoms and major depressive disorder (Onrust & Cuijpers, 2006; Vable et al., 2015), nutritional risk and weight loss (Stahl & Schulz, 2014), sleep problems (van de Straat & Bracke, 2015), poor immune response (Phillips et al., 2006), and mortality (Shor et al., 2012; Moon et al., 2011). Through increased stress, increased depressive symptoms and changes in the social network, spousal loss may also affect the cognitive functioning of older adults. However, previous research brought about mixed findings (compare Aartsen et al. (2005), Karlamangla et al. (2009), Mousavi-Nasab et al. (2012), and Vidarsdottir et al. (2014)). One reason might be that these studies often focused on widowhood as a state of being, rather than on the timing of the spousal loss (cf. Aartsen et al., 2005; Vidarsdottir et al., 2014). Since the negative effects of spousal loss on health outcomes tend to attenuate over time (Sasson & Umberson, 2014; Shor et al., 2012) it is important to take the timing of spousal loss into account. Another reason can be that few studies actually observed how cognitive functioning *changes* following spousal loss (see Karlamangla et al. (2009) for an exception). In the present study, we examine changes in cognitive functioning associated with spousal loss and potential gender differences in this association. The presented analyses address the role of time to/since the loss of the spouse and thus allow conclusions about the recovery from and anticipation of the loss.

1.1 Why spousal loss might affect cognitive functioning

Various explanations exist for a potential effect of spousal loss on cognitive functioning. Firstly, losing a spouse is typically considered to be one of the most stressful life events (Rosnick et al., 2010; Vidarsdottir et al., 2014). According to neuropsychological research, stress is detrimental for the brain because it may result in dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis which might lead to cognitive impairment (McEwen & Sapolsky, 1995; Lupien et al., 2007), particularly to impaired memory (Shields et al., 2017), but also to lower MMSE-scores

(Leng et al., 2013). Another explanation is that losing a spouse leads to increased levels of depressive symptoms, which in turn lead to lower levels of cognitive functioning (Aartsen et al., 2005). This assumption is supported by empirical findings showing that more depressive symptoms at one time point were associated with faster subsequent decline in processing speed (Comijs et al., 2001), global cognitive functioning (Wilson et al., 2004), and increased risk of developing Mild Cognitive Impairment (Barnes et al., 2006). Thirdly, losing a spouse often means the loss of one of the most important social contacts and thus the loss of a vital source of cognitive stimulation, which could further accelerate cognitive decline (van Gelder et al., 2006).

Empirical studies of losing a spouse mainly concentrated on effects on memory. For example, research among 35 to 85 year-olds from Sweden found that episodic but not semantic memory declined faster over a 5-year period in constantly widowed compared to constantly married persons (Mousavi-Nasab et al., 2012). Another investigation drawing on an earlier version of the data we use, but utilizing a less rigorous methodological approach and a smaller widower-sample, reported that older adults aged 60 years and older who became widowed during a 6-year period showed faster decline in memory than those staying married (Aartsen et al., 2005). Opposing our expectations, memory performance was independent of time since spousal loss in this investigation. In an Icelandic study, no effects of spousal loss were found on a number of cognitive functions, except for executive functioning among women (Vidarsdottir et al., 2014). None of these studies examined within person change in marital status and cognitive functioning, i.e. whether cognitive functioning changes as a consequence of losing the spouse. Rather, they compared married and widowed individuals. Reported effects might thus be confounded even though the authors tried to rule out alternative explanations. We know only one previous study that observed change in *both* marital status *and* cognitive functioning. It showed that loss (vs. no change or gain) of a partner was not associated with change in total cognition score and episodic memory (Karlamangla et al., 2009).

1.2 Gender differences in effects of spousal loss on cognitive change

In their work on gender differences in the health risks of widowhood, Stroebe et al. (2001) suggested that "men suffer relatively higher consequences of partner loss than do women" (also see Stroebe & Stroebe (1983)). Such effects have been found for some health related outcomes, e.g. frailty (Trevisan et al., 2016), grip strength (Clouston et al., 2014), and mortality (Moon et al., 2011). While previous research paid much attention to gender differences in effects of widowhood on subjective well-being, especially depressive symptoms (e.g. Nieboer et al., 1999; Lee et al., 2001; Lee & DeMaris, 2007; Lee et al., 1998; Umberson et al., 1992; Schaan, 2013), less is known about objective measures of cognitive functioning, specifically cognitive change in older adults.

Various lines of arguments can explain why effects of spousal loss on cognitive change might be stronger for men than for women. One is that the loss of the spouse forces particularly men from older cohorts with predominantly traditional gender roles to take over responsibility for traditionally female typed household tasks that they typically dislike or are unfamiliar with (Leopold & Skopek, 2016; Utz et al., 2004; South & Spitze, 1994; Umberson et al., 1992). This might cause stress that is detrimental to cognitive functioning. In contrast, women might experience less stress since they seem to derive self-confidence and satisfaction from carrying out traditionally male tasks (van den Hoonaard, 2009). Another reason might be men's stronger reliance on their spouses as confidants and for maintenance of social contacts (Stroebe & Stroebe, 1983; Cornwell et al., 2009). The resultant change in cognitive stimulation, the loss of access to social support, and the associated increase in stress and depressive symptoms may have consequences for cognitive functioning. Additionally, the generally smaller size of men's (vs. women's) confidant networks (Cornwell et al., 2009) and associated lower availability of social support in the case of spousal loss (Kalmijn, 2012) could be a reason why men suffer stronger consequences than women.

Empirical evidence for a male disadvantage in the consequences of spousal loss on cognitive change is however weak. In their studies, neither Aartsen et al. (2005) nor Mousavi-Nasab et al. (2012) found evidence of a significant gender difference in the effect of widowhood on memory decline. Vidarsdottir et al. (2014) even report that women but not men showed temporarily lower executive functioning in the 2-year interval after their spouse's death compared to the constantly married. No such effect was however found for memory and processing speed. Similarly, another study also reported a negative effect of widowhood for women but not for men (Vable et al., 2015). Interestingly however, episodic memory was lower in the 2-year interval *before* but not in the 2-year interval *after* onset of widowhood (compared to the constantly married), a finding that might be due to stressful caregiving or anticipation of spousal death.

1.3 This study

In the current study, we examine whether losing the spouse is associated with negative cognitive change over and above age-related cognitive change and whether there are gender differences in the strength of the effect of losing the spouse on cognitive change. To that end, we study the change in cognitive functioning in older adults who lost their spouse during the study using gender-stratified fixed effect regression models. Our analytical focus is on cognitive change at multiple time points after spousal loss. Additionally, observations before spousal loss allow inferences about pre-loss changes, e.g. due to stressful caregiving or anticipation.

2 Data and methods

The Longitudinal Aging Study Amsterdam (LASA; Hoogendijk et al., 2016; Huisman et al., 2011) is an ongoing longitudinal study among older adults in the Netherlands, initially based on a nationally representative sample. Data collection started in 1992/3 with respondents aged 55 to 85 years, followed up every three to four years thereafter. Sample selection occurred

randomly from municipal registries, with an oversampling of men and the oldest participants. Trained interviewers visited the respondents at home and conducted face-to-face main interviews, during which respondents were asked to fill in a drop-off questionnaire and to participate in a subsequent medical interview. Besides interviewer training, medical interviewers had to have a relevant professional background.

In the present study, we used data from seven waves (T_1=1992/3, T_2=1995/6, T_3=1998/9, T_4=2001/2, T_5=2005/6, T_6=2008/9, T_7=2011/2). Not least due to the assessment of some cognitive tests in main interviews and others in medical interviews, missing values differed by cognitive domain. Aiming to reduce sample selectivity, we included all observations providing sufficient information on a given outcome in our analyses, rather than using a joint sample with information present on all outcomes, at the cost of having different samples across outcomes. All analytical samples contain respondents who were recruited at T_1, and information on these respondents from follow-up interviews until T_7, i.e. a period of up to nearly 20 years. Respondents' observations were considered from age 65 onwards in order to focus on the age most relevant for cognitive decline. Among these observations, we identified the first observation in which a respondent provided valid information on a specific cognitive outcome and refer to this observation as the person- and outcome-specific baseline. The number of respondents married at baseline differed by outcome (n_{MMSE}=1,766, $n_{\text{Coding Task}}$=1,566, $n_{\text{Raven Matrices}}$=1,667, $n_{\text{15 Words Test}}$=1,593). Respondents with their baseline marital status being *never married*, *divorced* or *registered partnership* were not included in the analyses, the latter due to lacking information on the date of the partners' death. From the remaining sample, those transitioning from marriage to divorce (up to 4 respondents, depending on the outcome), those being married or in a registered partnership after widowhood (5 respondents), and those providing inconclusive information on their marital status (2 respondents) were excluded as well as those showing signs of dementia at baseline (MMSE < 24; up to 162 respondents). For technical reasons, observations with missing information on the variable measuring time to

spousal loss (4 respondents) and respondents providing only one observation of valid data (up to 341 respondents) also had to be excluded. The resulting analytical sample for MMSE consisted of 5,123 person-observations from 1,269 respondents, 419 of whom experienced spousal loss during the observed period (Coding Task: 4,248/1,100/368, Raven Matrices: 4,289/1,189/398, 15 Words Test: 4,319/1,112/376, respectively).

Outcome variables

Fluid cognitive abilities are more prone to age-related change than crystallized abilities (Lindenberger & Baltes, 1997) and might thus respond more sensitively to spousal loss. Thus, outcome variables comprise a widely used measure of global cognitive functioning and three measures of fluid cognitive abilities.

Global cognitive functioning (main interview) was measured using the Mini Mental State Examination (MMSE), a measure that comprises orientation in time and space, registration, attention, recall, language and visuospatial abilities (Folstein et al., 1975). MMSE scores can range from 0 to 30, with higher values indicating better functioning. Internal consistency is relatively low, representing the multidimensionality of the measure (Tombaugh & McIntyre, 1992).

Processing speed (medical interview) was assessed with a coding task that has been described by Piccinin & Rabbitt (1999). The test contains rows of letters, with each of the rows having an empty row below it. A key is provided with the test, showing pairs of letters that belong together. Respondents were asked to match as many letters that correspond to the letters in the upper rows as possible by naming the corresponding lower-row letter. We used the mean number of matches over three trials of one minute per assessment (observed range: 3.3 to 44.3), which correlated highly (Cronbach's $\alpha \geq .96$ for each wave).

Reasoning (main interview T_1-T_3, medical interview T_4-T_6, not assessed at T_7) was measured

using subsets A and B of the Raven Colored Progressive Matrixes (Raven, 1995), a nonverbal test of abstract reasoning. The test consists of 24 visual patterns that all miss a part of the pattern. From six alternatives printed underneath the patterns, respondents should choose the one that completes the pattern. Correct choices scored one point, thus the maximum score is 24. As intended, the items of both subsets as well as the subsets themselves increased in difficulty (van den Heuvel & Smits, 1994).

Memory (medical interview) was assessed with the delayed recall score of a 15 words test, a Dutch version of the Auditory Verbal Learning Test (Rey, 1964; Saan & Deelman, 1986). In three trials, respondents learn 15 words that they should recall after each trial. The delayed recall score is the number of correctly recalled words after a distraction period of 20 minutes following the learning phase. Correct recalls scored one point, thus up to 15 points could be achieved.

Predictor variables

Time to spousal loss indicates the duration between the cognitive assessment (main or medical interview, depending on outcome variable) and the date of the spouse's death. The date of the spouse's death was obtained from municipality registries if available and during the interviews otherwise. Durations were calculated using information on the month and year of these events, with 0 indicating that the cognitive assessment took place in the same month as the spouse deceased. For simplicity, we refer to the 1st year (0-11 months), 2nd year (months 12-23), 3rd year (months 24-35) and 4th and subsequent years (≥36 months) *after* spousal loss and the last year (months -12 to -1), 2nd year (months -13 to -24), 3rd year (months -25 to -36) and 4th and preceding years (months ≤-37) *before* spousal loss. The variable is a constant for those who did not lose their spouse during the observed period.

Age at the main or medical interview of each wave (depending on outcome variable), was measured for both respondents losing and respondents not losing their spouse, depending on

the outcome variable. To reduce collinearity when estimating effects of squared age, we centered the age variables to their respective mean value of all observations in a sample.

Gender was observed in the main interview at T_1 and was coded 0 for women and 1 for men.

Data analysis

Change in cognitive functioning associated with spousal loss was analyzed using fixed effects regression for panel data. This method uses the within-person change over time in the predictor variables (e.g. marital status) to predict within-person change in the outcome variable (e.g. cognitive functioning). Consequently, time-constant differences between persons are ruled out as confounding variables. The risk of time varying confounding is low since changes in e.g. respondents' health conditions or health behaviors might cause changes in their cognitive functioning but are unlikely to be the driving forces behind the spouses' deaths. Time since spousal loss relative to the reference period (i.e. the 4th year and previous years before the spouse's death) was modeled flexibly with multiple dummy variables, allowing to depict different trajectories, including anticipatory effects, effects of spousal loss and recovery. Accounting for age allows to disentangle loss-associated change from age-associated change in the outcomes. Since age was measured for both those losing and those not losing their spouse, the age-coefficient represents general age-related change rather than change of the spousal loss-population only. We split the analyses by gender and tested gender-differences with models interacting gender with both age and time to spousal loss. Since depressive symptoms constitute a potential pathway from spousal loss to change in cognitive functioning (Comijs et al., 2001; Barnes et al., 2006; Wilson et al., 2004; Vable et al., 2015; Sasson & Umberson, 2014), depressive symptoms are not controlled to allow detection of the total effect of spousal loss on cognitive change. Several sensitivity analyses were carried out. All analyses were conducted using Stata Version 14 (StataCorp, 2015).

3 Results

3.1 Descriptive results

In the largest sample (MMSE), 55% of observations were from male respondents and 38% from respondents losing their spouse during the observation period, with an average age of about 76 years (Table 1; Online Supplements A1-A3 for the other samples). About 9 educational years were attained on average, and almost all observations were from respondents indicating Dutch ethnicity. In terms of health, at least one functional limitation was present in about 56% of observations, with an average of 2 chronic diseases and about 8 depressive symptoms (CES-D Scale; Radloff, 1977). There were no substantial differences between the samples on these variables. Average age was higher among observations from male compared to female respondents (except for Coding Task and 15 Words Test) and among those losing their spouse compared to those not losing their spouse. While almost 70% of observations were from male respondents among those not losing the spouse, only about 35% were from male respondents among those losing their spouse. Average cognitive functioning-scores were higher among female (vs. male) respondents (reversed pattern for Raven Matrices) and those not losing their spouse (vs. those losing their spouse; except for 15 Words Test).

3.2 Fixed effects regression models

Results from fixed effects models for women and men are displayed in Tables 2 and 3, respectively, and in Figure 1. The variable time to spousal loss indicates the difference between the mean cognitive functioning score of the reference period (i.e. the 4^{th} year and previous years before the spouse's death) and the mean score of the period under consideration. For both men and women, the terms for linear and squared age jointly indicate accelerated age-related decline in MMSE, Coding Task and 15 Words Test, but linear decline of Raven Matrices.

3.2.1 MMSE

With some fluctuation in the time before spousal loss, MMSE-scores among women declined in the second year after the spouse's death ($B_{+2nd\ year}$=-0.68, p=.047) and returned towards the level of the reference period (i.e. the 4th year and previous years before the spouse's death) thereafter. The observed difference between the reference period and the second year after spousal loss corresponds to the age-related cognitive decline occurring during 4.20 years after the mean age of 75.98 years ($B_{age\ linear}$ * age + $B_{age\ squared}$ * age^2=-0.12 * age + (-0.01) * age^2=-0.68; solved for age: age=4.20 years, with age=0 equaling the average age in the joint MMSE-sample for both women and men due to centering). The pattern for men was comparable to that of women, but the decrease of 0.52 MMSE-points in the second year after spousal loss (corresponding to 2.77 years of age-related decline after the mean age) failed statistical significance (p=.313). No significant gender differences for loss-associated change in MMSE were found (all $p\geq$.233).

3.2.2 Coding Task

Statistically controlling for age, the Coding Task-scores showed a minor and non-significant decline for women ($B_{-3rd\ year}$=-0.73, p=.076; $B_{-2nd\ year}$=-0.79, p=.122) and an increase for men *before* the loss of the spouse ($B_{-3rd\ year}$=1.34, p=.012), with a significant gender-difference in change between the reference period and the third year before spousal loss (p=.002). More importantly however, neither men nor women showed a change in Coding Task immediately before the spouse's death or thereafter in comparison to the reference period, but rather tended to show a slight increase in the longer run (women: $B_{+\ 4th\ and\ subs.\ years}$=0.72, p=.106; men: $B_{+\ 4th\ and\ subs.\ years}$=0.84, p=.186).

3.2.3 Raven Matrices

As concerns the Raven Matrices-scores, there was some fluctuation before and after spousal loss, with the strongest but temporary difference to the reference period in the second year after

spousal loss among women ($B_{+2nd\ year}$=-1.54, p<.001), corresponding to 11.85 years of age-related cognitive decline ($B_{+2nd\ year}$ / B_{age} = -1.54 / -0.13 = 11.85 years; only the linear term for age is considered here due to non-significance of the squared term). No such effect was observed among men (gender difference in the second year after spousal loss: p=.005), but they tended to show weaker losses compared to the reference period – corresponding to about 4 years of age-related decline – in the year before spousal loss ($B_{last\ year\ before}$=-0.76, p=.105) and in the longer run ($B_{+\ 4th\ and\ subs.\ years}$=-0.73, p=.095)

3.2.4 15 Words Test

For both men and women, the 15 Words Test-scores only showed some minor and statistically non-significant fluctuation around the scores of the reference period (all $p \geq .494$).

3.3 Sensitivity analyses

3.3.1 Bonferroni adjustment

Responding to α-error inflation in multiple testing, we consulted Bonferroni-adjusted significance tests. Since a single significant coefficient out of three or four coefficients would lead to the rejection of the null-hypothesis of no effect before or after spousal loss, respectively, correction for multiple testing is appropriate (Perneger, 1998). Corrected critical p-values are .05/3=.016 and .05/4=.012, respectively (Bender & Lange, 2001). Given the adjusted p-values, differences in MMSE are no longer significant, but conclusions regarding Processing Speed and Raven Matrices remain unchanged.

3.3.2 Practice effects

Practice effects were controlled by adding to the original models a dummy variable identifying the first observation in which a given cognitive test was completed. A statistically significant practice effect (i.e. lower cognitive scores at the first assessment than thereafter) was only found

for the 15 Words Test. The conclusions from this sensitivity analysis were generally in accord with our original results (see Online Supplements B1 and B2).

3.3.3 ln(31-MMSE)-transformation

To adjust the skewed distribution of MMSE-residuals, a ln(31-MMSE)-transformation was used. The decrease in MMSE in the second year after spousal loss for women failed statistical significance in analyses of the ln(31-MMSE)-transformed variable ($B_{+2nd\ year}$=0.13 p=.068; note that higher scores represent lower functioning on the transformed variable; see Online Supplement C1).

3.3.4 Linear change before and after spousal loss

More long-term trends in cognitive change following spousal loss were examined in fixed effects models with two metric variables indicating years before or after spousal loss, respectively, and being 0 otherwise (range: -19 to 19 years). Except for substantially very weak positive developments on the Coding Task before (women: B=0.08, p=.083; men: B=0.12, p=.034) and after spousal loss (women: B=0.09, p=.070), neither time before nor time after spousal loss was related to cognitive functioning when age was accounted for (see Online Supplements D1 and D2). Additional F-tests did not reveal differences between pre- and post-loss slopes, and these differences did not differ by gender (all $p \geq .05$).

3.3.5 Random effects models

In addition to the original fixed effects models, random effects models were inspected. Hausman tests (Andreß et al., 2013) indicated endogeneity for MMSE (women and men) and for Raven Matrices (men), a situation in which fixed effects models are to be preferred over the more efficient but inconsistent random effects models. Random effect models specified analogous to the fixed effects models, but with educational years as an additional time-constant control variable, confirmed the conclusions from the fixed effects models, except that the

increase in Coding Task scores in the third year before spousal loss among men was smaller and of borderline significance (B=1.02; p=.05; Online Supplements E1 and E2).

3.3.6 Change in depressive symptoms

We aimed to corroborate our findings by examining whether previous reports of increased depressive symptoms among widowed persons – especially men – can be reproduced using our data and method (e.g. Stroebe & Stroebe, 1983; Stroebe et al., 2001; Lee et al., 2001; Lee & DeMaris, 2007; Vable et al., 2015). Higher scores on the Center for Epidemiologic Studies Depression Scale (CES-D Scale; Radloff, 1977) indicate more self-reported depressive symptoms during the last week (range: 0 to 60). Compared to the fourth and previous years before spousal loss, CES-D-scores were significantly increased in the three years after spousal loss among women ($B_{+1st\ year}$=3.78, $p\leq$.001; $B_{+2nd\ year}$=5.56, $p\leq$.001; $B_{+3rd\ year}$=3.18, p=.001, $B_{+4th\ and\ subs.\ years}$=1.32, p=.058). Among men, a significant increase in CES-D scores was already observed somewhat earlier ($B_{-1st\ year}$=2.44, p=.033) but the increase thereafter tended to be less pronounced ($B_{+1st\ year}$=2.56, p=.003; $B_{+2nd\ year}$=3.15, p=.002). Gender differences in the change of depressive symptoms failed conventional levels of significance (all $p\geq$.070) (see Online Supplements F1-F3). The increase in depressive symptoms is largely in line with earlier findings of increased depressive symptoms before and after spousal loss for both men and women (Vable et al., 2015). The absence of gender differences in effects of spousal loss on change in depressive symptoms is contradictory to some cross-sectional findings (e.g. Lee et al., 2001), but in line with recent longitudinal research examining trajectories of post-widowhood depressive symptoms net of prewidowhood levels and widowhood duration (Sasson & Umberson, 2014).

3.3.7 Attrition analysis

Selective panel attrition directly before or after spousal loss might cause underestimation of the association between spousal loss and cognitive change if the likelihood of attrition in

association with spousal loss is larger for those experiencing a larger negative change in cognitive functioning than for those experiencing a smaller negative loss-associated cognitive change. It is in the nature of panel attrition that the change in cognitive functioning potentially causing non-participation cannot be observed. However, it is possible to use information measured at wave *T*, including time to spousal loss, cognitive functioning, and an interaction term of both variables to estimate the likelihood of attrition for other reasons than the respondent's own death at wave T_{+1}.

Average marginal effects from logistic regression models indicated that the difference in the likelihood of attrition in the third year (compared to the fourth and previous years) before spousal loss increased by about 10 percentage points for each standard deviation decrease in the respective cognitive function (see Online Supplement G). Since the analyses concern attrition at the next wave (i.e. 3 to 4 years later), the models suggest that the likelihood of attrition in the years directly following spousal loss is indeed larger for those ever-widowed respondents with lower cognitive functioning. However, it remains unclear if they are also the ones that experience the largest change in their cognitive functioning in association with spousal loss.

4 Discussion

We examined the effect of spousal loss on change in older adults' cognitive functioning and investigated (1) whether losing the spouse is associated with a negative cognitive change over and above the effect of age-related cognitive change, and (2) whether gender differences exist regarding the strength of the effect of spousal loss on cognitive change. We used fixed effects regression models controlling for age and time-constant confounders to analyze effects on general cognitive functioning, processing speed, reasoning, and memory. There was little evidence of spousal loss being associated with cognitive change, except that women on average showed a robust temporary decrease in reasoning scores in the second year after spousal loss.

No robust effect was observed for men. Evidence that "widowhood effects" might occur in anticipation of the spouse's death (Vable et al., 2015) was weak. For men, an increase in processing speed was observed in the third year before the spouse's death; however, the effect should not be overemphasized because it was relatively small and only of borderline significance in the more efficient random effects model. Across all four cognitive domains, men did not show a more disadvantaged pattern of cognitive change associated with spousal loss, which is in contrast to earlier research on gender differences in other domains of health, but in line with previous findings on cognitive functioning (e.g. Aartsen et al., 2005). Instead, our findings provide support to earlier findings that women's cognitive functioning may be more negatively affected than men's (Vidarsdottir et al., 2014). Comparable to our findings, Vidarsdottir et al. (2014) report the two-year-interval following spousal loss as the critical period. Furthermore, the absence of an effect of change in marital status on memory change in our study is in contrast to reports of faster memory decline among widowed (vs. married) persons (Aartsen et al., 2005; Mousavi-Nasab et al., 2012), a diverging pattern that has previously been found by Karlamangla et al. (2009).

4.1 Implications

Implications from our study are based on the overall finding that there were few detrimental effects of spousal loss beyond age-related cognitive decline, and those observed were temporary and found in women only. Firstly, the changes in potential pathways caused by spousal loss, i.e. in stress, depressive symptoms, and cognitive stimulation, might not be severe enough to trigger changes in cognitive functioning. As regards the potential for cognitive stimulation, Kalmijn (2012) found that although women but not men experience increased support from family, friends and neighbors when becoming widowed, neither women nor men experience a *decrease* in support or contact frequency from these groups (Kalmijn, 2012), calling into question both the idea that spousal loss leads to a decrease of cognitive stimulation and does so

more for men. Secondly, it might be the case that changes in the potential pathways are not universally related to cognitive change, e.g. stress was not associated with processing speed in a small scale study among adults of a wide age range (VonDras et al., 2005), and only a selection of cognitive domains was found to be associated with depressive symptoms in another study (Dotson et al., 2008). Yet others found that memory predicted change in depressive symptoms rather than depressive symptoms predicting memory change (Jajodia & Borders, 2011). Thirdly, it might be the case that the suggested pathways actually exist, and the absence or temporariness of effects could be explained by accompanying beneficial processes. The concept of cognitive plasticity (Lövdén et al., 2010) suggests that a decrease in cognitive functioning following spousal loss may induce a mismatch between environmental demands and cognitive supply, which can trigger a (re-)adaptation of cognitive functioning to the demands. The complete absence of an effect of spousal loss in other domains suggests that adaptation can either happen quickly or that beneficial consequences counteract the negative consequences of spousal loss. E.g., learning to carry out tasks that were previously taken care of by the spouse may foster cognitive functioning, comparably to the beneficial effects of acquiring another language (Bak et al., 2014). Similarly, one reason for the absence of a disadvantage for men might be that carrying out disliked household tasks causes new stimulation and only mild stress, which has been suggested to stimulate cognitive functioning (Comijs et al., 2011). Fourthly, effect heterogeneity based on other characteristics than gender might explain our findings. E.g., spousal loss might be less anticipated, more stressful and more detrimental to cognitive functioning if the deceased partner was younger or in better health. Furthermore, personality characteristics or spousal care activities of the bereaved person might be important factors causing variation in response to spousal loss. To further explore this possibility, future research might want to depart from the examination of gender differences and instead focus on other characteristics of individuals, couples, and circumstances of the spouse's death that can affect the reaction to losing a spouse (Carr, 2004).

4.2 Limitations

A first limitation of our study is the relatively small number of observations from men in some periods before and after spousal loss, making it harder to detect statistically significant effects for men or gender differences. However, the substantial patterns suggested that the absence of effects was not due to low power, and a statistically significant gender difference was observed in reasoning nevertheless. Secondly, we report yearly changes in cognitive functioning at the aggregate level even though individuals were surveyed in intervals of about three years. Since a short temporary effect of spousal loss would remain undiscovered if three-year intervals were examined, we preferred to use variation in the date of the spouse's death to be able to report on shorter time intervals, at the cost of not observing each individual in each interval. Although it is plausible that spousal loss triggers more long-term cognitive decline during many years after the loss, this was not supported by sensitivity analyses of linear change during up to 19 years after spousal loss. Thirdly, we exploited all available information by using all observations with valid data, at the cost of slightly different samples for different outcomes. However, this is unlikely to be the driver behind different findings since these samples did not differ substantially by age, gender, spousal loss, education or health. Fourthly, our findings might underestimate effects of spousal loss on cognitive decline if the likelihood of panel attrition associated with spousal loss is higher for those showing larger cognitive decline in association with spousal loss. Due to the very nature of panel attrition, we were unable to examine whether cognitive decline and panel attrition following spousal loss were associated. The approximation of cognitive decline using the level of cognitive functioning at the previous wave suggested selective attrition and thus underestimation of effects of spousal loss on cognitive decline in our study. This conclusion however only holds if a lower level of cognitive functioning at the previous wave is associated with larger decline of cognitive functioning experienced in association with spousal loss. Nevertheless, potential underestimation was not severe enough

to mask effects of spousal loss on reasoning for women or on depressive symptoms. However, the absence of additional effects in our study could be due to panel attrition.

4.3 Conclusion

So far, few studies examined the association between losing the spouse and cognitive change. This population-based study suggests that cognitive functioning is on average hardly affected by spousal loss in the subsequent years. At least for the cognitive domain, this contradicts the notion that becoming widowed accelerates the progression of frailty in older adults. In contrast, older adults' cognitive functioning seems to be rather resilient against this very stressful experience, which might possibly be explained by cognitive plasticity.

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Table 1: Descriptive statistics for analysis of MMSE.

MMSE	Total	Women	Men	*p* for gender diff.
Whole sample				
$n_{observations}$	*5,123*	*2,299*	*2,824*	
MMSE, mean ± SD	27.26 ± 2.60	27.34 ± 2.53	27.19 ± 2.66	.033
Age, mean ± SD	75.98 ± 6.60	75.71 ± 6.58	76.21 ± 6.62	.007
Male, n (%)	2,824 (55.1)	--	--	--
Losing spouse, n (%)	1,958 (38.2)	1,288 (56.0)	670 (23.7)	<.001
Not losing spouse				
$n_{observations}$	*3,165*	*1,011*	*2,154*	
MMSE, mean ± SD	27.35[a] ± 2.60	27.53[b] ± 2.47	27.26[c] ± 2.66	.006
Age, mean ± SD	74.86[d] ± 6.05	74.04[e] ± 5.75	75.24[f] ± 6.14	<.001
Male, n (%)	2,154 (68.1[g])	--	--	
Losing spouse				
$n_{observations}$	*1,958*	*1,288*	*670*	
MMSE, mean ± SD	27.11[a] ± 2.59	27.20[b] ± 2.57	26.96[c] ± 2.64	.054
Age, mean ± SD	77.80[d] ± 7.05	77.01[e] ± 6.89	79.32[f] ± 7.11	<.001
Male, n (%)	670 (34.2[g])	--	--	--
Time to spousal loss, n (%)				.019
≤ -37 months	688 (35.1)	424 (32.9)	264 (39.4)	
-36 to -25 months	127 (6.5)	83 (6.4)	44 (6.6)	
-24 to -13 months	129 (6.6)	83 (6.4)	46 (6.9)	
-12 to -1 months	101 (5.2)	69 (5.4)	32 (4.8)	
0 to 11 months	131 (6.7)	81 (6.3)	50 (7.5)	
12 to 23 months	126 (6.4)	80 (6.2)	46 (6.9)	
24 to 35 months	107 (5.5)	72 (5.6)	35 (5.2)	
≥ 36 months	549 (28.0)	396 (30.8)	153 (22.8)	

Note. SD = standard deviation; *p*-values were derived from two-sided *t*-tests for mean values, *p*-tests for shares, and a χ^2-test for the distribution of observations by time to spousal loss and gender, respectively.

Identical superscript letters indicate significant differences between those losing spouse and those not losing spouse with $p < .05$.

Observations belong to 1,269 respondents (533 female, 736 male), 419 of whom lost their spouse (270 female, 149 male).

Table 2: Main effects of time to spousal loss and age predicting cognitive functioning in older women.
Unstandardized coefficients, 95%-confidence intervals, and *p*-values for gender differences from fixed effects regression models.

Women	***MMSE***			***Coding Task***			***Raven Matrices***			***15 Words Test***		
	B	*95%-CI*	*p for gender diff.*	*B*	*95%-CI*	*p for gender diff.*	*B*	*95%-CI*	*p for gender diff.*	*B*	*95%-CI*	*p for gender diff.*
Age	-0.12***	[-0.15,-0.10]	.081	-0.37***	[-0.41,-0.33]	**.014**	-0.13***	[-0.17,-0.10]	**.044**	-0.13***	[-0.16,-0.10]	.325
Age^2	-0.01***	[-0.01,-0.00]	.376	-0.01***	[-0.02,-0.01]	.131	-0.00	[-0.01,0.00]	.254	-0.00***	[-0.01,-0.00]	.188
Time to spousal loss (ref. ≤ -4th year)												
- 3rd year	-0.14	[-0.68,0.40]	.233	-0.73	[-1.53,0.08]	**.002**	0.10	[-0.52,0.73]	.655	-0.09	[-0.60,0.43]	.783
- 2nd year	-0.37	[-1.00,0.27]	.532	-0.79	[-1.79,0.21]	.071	-0.69	[-1.45,0.07]	.481	-0.12	[-0.75,0.51]	.972
- 1st year	-0.00	[-0.58,0.58]	.573	-0.05	[-0.86,0.75]	.345	-0.06	[-0.81,0.69]	.248	0.09	[-0.55,0.73]	.594
+ 1st year	-0.34	[-0.92,0.23]	.252	0.28	[-0.72,1.28]	.701	-0.24	[-0.91,0.44]	.887	0.08	[-0.57,0.72]	.757
+ 2nd year	-0.68*	[-1.35,-0.01]	.802	0.04	[-0.95,1.02]	.353	-1.54***	[-2.31,-0.78]	**.005**	0.21	[-0.44,0.87]	.827
+ 3rd year	-0.03	[-0.64,0.57]	.669	0.24	[-0.83,1.30]	.613	-0.29	[-1.09,0.52]	.539	-0.32	[-1.22,0.59]	.575
≥ + 4th year	-0.19	[-0.73,0.34]	.764	0.72	[-0.15,1.58]	.868	-0.57	[-1.30,0.16]	.781	0.09	[-0.51,0.68]	.549
Constant	27.70***	[27.50,27.90]	--	25.06***	[24.77,25.34]	--	18.18***	[17.95,18.40]	--	6.64***	[6.45,6.83]	--
$N_{observations}$		2,299			1,847			1,872			1,889	
$N_{individuals}$		533			451			492			456	
AIC		8861.42			8363.48			7941.33			7475.16	
BIC		8913.08			8413.18			7991.15			7525.05	

Note. *p*-values for gender differences were obtained from a joint model for women and men where all variables were interacted with gender.
Bold letters highlight gender differences with $p < .05$
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 3: Main effects of time to spousal loss and age predicting cognitive functioning in older men.
Unstandardized coefficients, 95%-confidence intervals, and *p*-values for gender differences from fixed effects regression models.

Men	***MMSE***			***Coding Task***			***Raven Matrices***			***15 Words Test***		
	B	*95%-CI*	*p for gender diff.*	*B*	*95%-CI*	*p for gender diff.*	*B*	*95%-CI*	*p for gender diff.*	*B*	*95%-CI*	*p for gender diff.*
Age	-0.16***	[-0.18,-0.13]	.081	-0.44***	[-0.48,-0.40]	**.014**	-0.18***	[-0.21,-0.15]	**.044**	-0.11***	[-0.14,-0.09]	.325
Age^2	-0.01***	[-0.01,-0.00]	.376	-0.01***	[-0.01,-0.00]	.131	-0.00	[-0.00,0.00]	.254	-0.00*	[-0.00,-0.00]	.188
Time to spousal loss (ref. ≤ -4th year)												
- 3rd year	0.37	[-0.28,1.02]	.233	1.34*	[0.29,2.40]	**.002**	-0.14	[-1.02,0.74]	.655	0.04	[-0.72,0.80]	.783
- 2nd year	-0.08	[-0.74,0.59]	.532	0.65	[-0.55,1.86]	.071	-0.28	[-1.13,0.56]	.481	-0.10	[-0.71,0.50]	.972
- 1st year	0.26	[-0.46,0.98]	.573	0.66	[-0.59,1.92]	.345	-0.76	[-1.68,0.16]	.248	-0.20	[-1.06,0.66]	.594
+ 1st year	0.22	[-0.56,1.00]	.252	0.62	[-0.80,2.04]	.701	-0.32	[-1.21,0.57]	.887	0.23	[-0.53,1.00]	.757
+ 2nd year	-0.52	[-1.54,0.49]	.802	0.76	[-0.42,1.94]	.353	0.19	[-0.74,1.12]	**.005**	0.11	[-0.55,0.77]	.827
+ 3rd year	-0.27	[-1.15,0.61]	.669	0.65	[-0.56,1.87]	.613	0.17	[-1.05,1.39]	.539	0.05	[-0.86,0.96]	.575
≥ + 4th year	-0.04	[-0.86,0.78]	.764	0.84	[-0.41,2.09]	.868	-0.73	[-1.59,0.13]	.781	-0.18	[-0.84,0.47]	.549
Constant	27.45***	[27.33,27.58]	--	24.32***	[24.16,24.47]	--	18.43***	[18.33,18.54]	--	5.14***	[5.03,5.24]	--
$N_{observations}$		2,824			2,401			2,417			2,430	
$N_{individuals}$		736			649			697			656	
AIC		10982.47			10912.61			9776.80			8985.41	
BIC		11035.99			10964.66			9828.92			9037.57	

Note. *p*-values for gender differences were obtained from a joint model for women and men where all variables were interacted with gender.
Bold letters highlight gender differences with $p < .05$.
* $p < .05$, ** $p < .01$, *** $p < .001$.

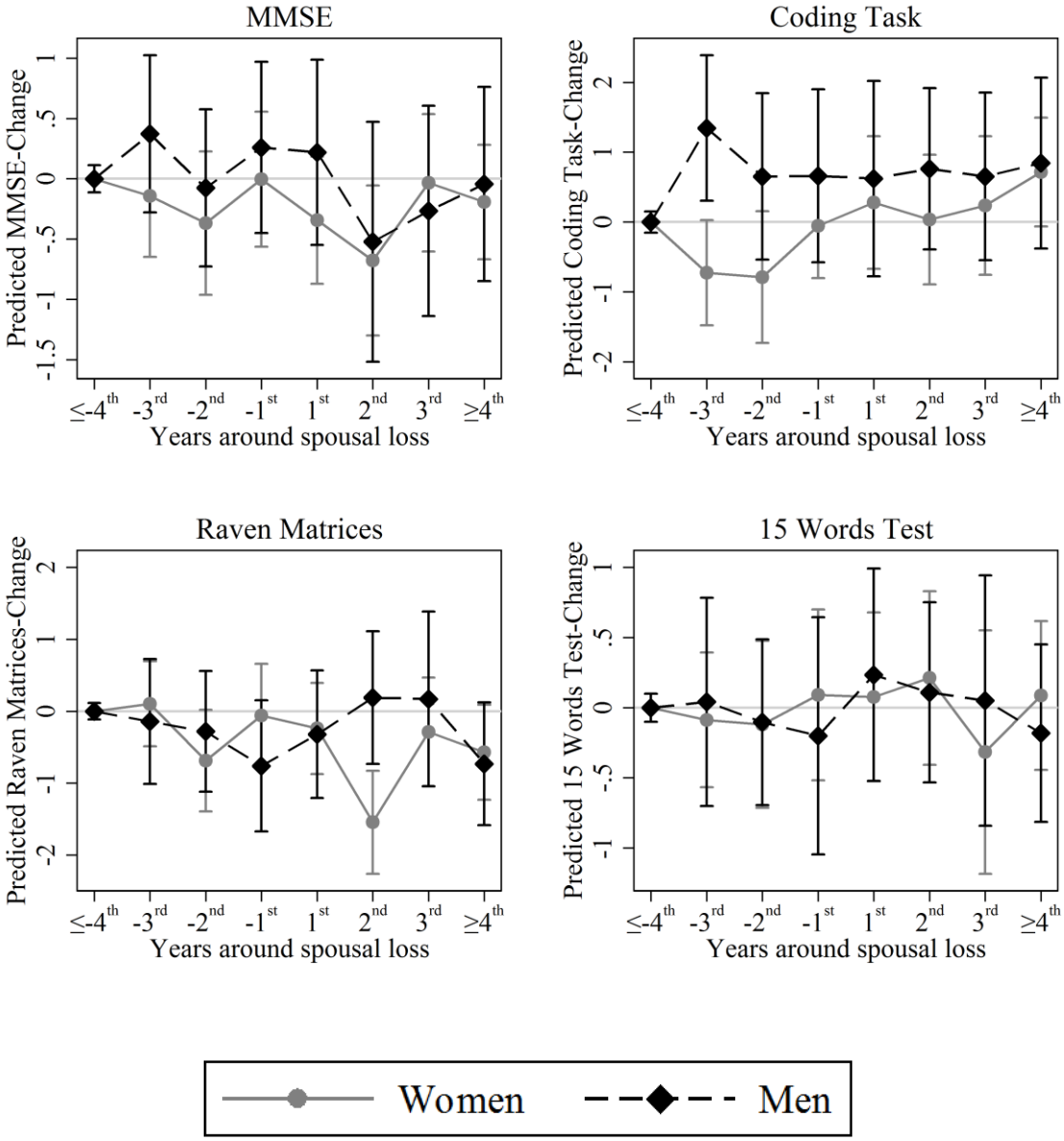
MMSE
Predicted MMSE-Change
-1.5 -1 -.5 0 .5 1
Coding Task
Predicted Coding Task-Change
-2 -1 0 1 2
Raven Matrices
Predicted Raven Matrices-Change
-2 -1 0 1 2
15 Words Test
Predicted 15 Words Test-Change
-1 -.5 0 .5 1
≤-4th -3rd -2nd -1st 1st 2nd 3rd ≥4th
Years around spousal loss
Women
Men

Figure 1: Development of four domains of cognitive functioning over time relative to spousal loss under control of age-related decline, separately for women and men. Scores for the reference period (4th and previous years) were set to 0 for the graphs to show the change relative to the reference period.

Results are from fixed effects models with age and time to spousal loss interacted with gender.