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Relational memory and self-efficacy measures reveal distinct profiles of subjective memory concerns in older adults

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Abstract

OBJECTIVE—Subjective memory concerns (SMCs) in healthy older adults are associated with future decline and can indicate preclinical dementia. However, SMCs may be multiply determined, and often correlate with affective or psychosocial variables rather than with performance on memory tests. Our objective was to identify sensitive and selective methods to disentangle the underlying causes of SMCs.

METHOD—Because preclinical dementia pathology targets the hippocampus, we hypothesized that performance on hippocampally-dependent relational memory tests would correlate with SMCs. We thus administered a series of memory tasks with varying dependence on relational memory processing to 91 older adults, along with questionnaires assessing depression, anxiety, and memory self-efficacy. We used correlational, regression, and mediation analyses to compare the variance in SMCs accounted for by these measures.

RESULTS—Performance on the task most dependent on relational memory processing showed a stronger negative association with SMCs than did other memory performance metrics. SMCs were also negatively associated with memory self-efficacy. These two measures, along with age and education, accounted for 40% of the variance in SMCs. Self-efficacy and relational memory were uncorrelated and independent predictors of SMCs. Moreover, self-efficacy statistically mediated the relationship between SMCs and depression and anxiety, which can be detrimental to cognitive aging.

CONCLUSIONS—These data identify multiple mechanisms that can contribute to SMCs, and suggest that SMCs can both cause and be caused by age-related cognitive decline. Relational memory measures may be effective assays of objective memory difficulties, while assessing self-efficacy could identify detrimental affective responses to cognitive aging.

Keywords

subjective memory concerns; cognitive aging; self-efficacy; relational memory; Alzheimer's disease

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INTRODUCTION

The neuropathological processes that give rise to age-related neurodegenerative disorders such as Alzheimer's Disease (AD) begin many years before current diagnostic criteria are met. The ability to understand and identify preclinical disease symptoms is crucial, as preclinical periods may present critical opportunities for intervention. Subjective memory concerns (SMCs), which reflect the subjective impression of declining memory abilities despite normal neuropsychological test performance, may indicate preclinical pathology in some individuals.

Indeed, SMCs have been associated with subsequent dementia (Donovan et al., 2014; Jessen et al., 2010; Luck et al., 2010; van Oijen, de Jong, Hofman, Koudstaal, & Breteler, 2007), future cognitive decline (Glodzik-Sobanska et al., 2007; Hohman, Beason-Held, Lamar, & Resnick, 2011; Reisberg, Shulman, Torossian, Leng, & Zhu, 2010), and the presence of AD-related biomarkers in cognitively healthy older adults (Amariglio et al., 2012; Jessen et al., 2006; Merrill et al., 2012; Saykin et al., 2006; Stewart et al., 2008; Striepen et al., 2010; van der Flier et al., 2004). However, the prognostic value of SMCs are currently limited by their high prevalence among older adults, as well as the weak or nonexistent associations between subjective and objective memory performance that have been noted in a large number of published reports (e.g., Balash, Mordechovich, Shabtai, Merims, & Giladi, 2010; Bartley et al., 2012; Brucki & Nitrini, 2009; Hohman et al., 2011; Jessen et al., 2006; Jorm et al., 2004; Kim, 2013; Minett, Da Silva, Ortiz, & Bertolucci, 2008; Reid & MacLulich, 2006; Saykin et al., 2006; Slavin et al., 2010; Stewart et al., 2008, 2011; Striepen et al., 2010; van der Flier et al., 2004). The goals of the present research are thus to: 1) test the hypothesis that we can identify cognitive deficits associated with SMCs by employing sufficiently sensitive and selective memory tests, and 2) investigate the relationship between these memory deficits and certain affective and psychosocial factors that commonly co-occur with memory concerns.

Early AD-related neuropathology and tissue loss occurs in the hippocampus and its major cortical inputs (Braak & Braak, 1991). Consistent with long-standing associations between these brain regions and long-term memory, neuropsychological tests involving delayed recall of stimuli such as stories or words are among the most effective early-diagnostic tools in current use (Albert et al., 2011; Backman, Small, & Fratiglioni, 2001; Visser, Verhey, Ponds, Kester, & Jolles, 2000). However, such tests have often failed to detect differences in performance between low- and high-SMC older adults, even in studies where neuroimaging measures confirmed group differences in hippocampal structural integrity (e.g., Saykin et al., 2006; Striepen et al., 2010; van der Flier et al., 2004).

Here we draw upon significant recent advances in our understanding of the functional role of the hippocampus and related medial temporal lobe regions in cognition so as to identify measures with improved sensitivity to corroborate subjective reports of memory deficits. Substantial recent evidence points to the representational demands imposed by a given memory task as a more precise determinant of hippocampal involvement and functional integrity than is the delay per se. In particular, tasks that require relational memory

processing—or the ability to construct representations of arbitrary relationships among individual stimuli—have been shown to engage the hippocampus even at minimal delays (e.g., Konkel, Warren, Duff, Tranel, & Cohen, 2008; Monti et al., 2015; Watson, Voss, Warren, Tranel, & Cohen, 2013). By this account, the diagnostic utility of recall tests may stem largely from the requirement that patients create relational representations of to-be-recalled information. For example, performance on word recall tests depends on the binding of commonly-encountered words to the spatial and temporal context of the testing environment, whereas the recall of stories requires elements such as characters, locations, and temporal sequences of events to be bound into relational representations. Importantly, this account further predicts that our ability to corroborate perceived memory impairments may be improved by the inclusion of tests that are designed to place maximal demands on relational memory processing.

Previous research suggests that tests involving the *reconstruction* of recently-encountered events may be promising in this regard. Reconstruction tasks often require participants to view spatial displays and then attempt to recreate them from memory. A valuable attribute of such tasks is their use of a continuous response space to assess object-location memory, which provides insight into the *type* as well as the amount of memory errors that are committed. In particular, studies of spatial reconstruction performance in patients with hippocampal lesions (Watson et al., 2013) as well as other medical conditions that target the hippocampus (Pertsov et al., 2013) indicate that hippocampal damage is disproportionately associated with tendencies to “swap” or reverse the relative positions of two items within a given display. For example, hippocampal patients in Watson et al. (2013) exhibited a striking 40-fold increase in swap error rates relative to control participants, even on trials that contained only a single pair of objects. By contrast, overall item misplacement (e.g., the average distance from the geographic centers of each item’s actual and reconstructed location) evinced a comparatively modest 2–4-fold increase in hippocampal patients, as did a number of other error metrics.

These data suggest that swap errors are particularly sensitive to hippocampal integrity, likely by virtue of their fundamental relationship to relational binding. Generic spatial memory metrics such as misplacement are also relational to some degree, particularly insofar as item locations are represented in memory as a series of arbitrary and independent Cartesian coordinates. However, individuals with reduced hippocampal function seem able to take advantage of alternate representational options, such as higher-order “shapes” or outlines formed by perceptual closure within the displays, to retain some ability to reconstruct their overall geometries despite an inability to correctly assign items to vertices (see Uttal & Chiong, 2004, for similar evidence of this type of spatial memory strategy in children). Swap errors during spatial reconstruction tasks are also tightly linked to hippocampal integrity in non-clinical populations, as evidenced by a recent finding that hippocampal volumes in healthy middle aged and older adults correlate more robustly with the aforementioned “swap” metric during spatial reconstruction than with performance on traditional delayed recall tests (Monti et al., 2015). For these reasons, we predicted that swap error rates during a spatial reconstruction task would correlate with reports of SMCs in healthy older adults.

The dearth of reported associations between SMCs and objective measures of cognition stands in stark contrast to numerous reports of correlations between SMCs and affective factors such as depression or anxiety (Balash et al., 2010; Bartley et al., 2012; Brucki & Nitrini, 2009; Jessen et al., 2007; Jorm et al., 2004; Kim, 2013; Minett et al., 2008; Reid & MacLulich, 2006; Slavin et al., 2010), as well as psychosocial constructs such as memory self-efficacy (Mol, Ruiter, Verhey, Dijkstra, & Jolles, 2008). However, the relationship between these variables and cognitive performance is unclear. One report found impaired delayed recall performance only in those high-SMC participants with lower levels of depression, suggesting that depression may be unrelated to any potential cognitive underpinnings of SMCs (Jessen et al., 2007). However, other research suggests that affective or psychosocial aspects of memory concerns should interact with memory performance (Donovan et al., 2014; Kremen, Lachman, Pruessner, Sliwinski, & Wilson, 2012; Rothman & Mattson, 2010; Sotiropoulos et al., 2008). Evidence of such interrelatedness would have clinical significance, given that both negative affect and memory controllability beliefs are modifiable (Lachman, Weaver, Bandura, Elliot, & Lewkowicz, 1992; West, Bagwell, & Dark-Freudeman, 2008). We thus assessed levels of depression, anxiety, and memory self-efficacy in our participants so as to determine the extent to which the relationship of these variables with SMCs may either contribute to or be dependent upon any corresponding associations with cognitive performance.

METHODS

Participants

Ninety-one adults between the ages of 61–81 years from the Champaign-Urbana community participated. Because our focus was on older adults without overt cognitive difficulties, we excluded from analyses the 20% of participants ($n = 18$) who scored the lowest on a composite measure of five validated neuropsychological tests (see Supplemental Table 1 for psychometric data from these excluded participants). One additional participant was excluded due to data corruption. Demographic information and key variables of interest for the remaining 72 participants are summarized in Table 1. Participants completed a consent form approved by the University of Illinois at Urbana-Champaign institutional review board prior to participating and were compensated at a rate of \$10/hour.

Measures

Subjective Memory Concerns (SMCs)—SMCs were assessed using the Memory Functioning Questionnaire (MFQ), a 64-item questionnaire that evaluates self-perception of everyday memory function (Gilewski, Zelinski, & Schaie, 1990). Several previous studies have established relationships between MFQ scores in healthy older adults and the presence of AD-related biomarkers, including amyloid plaques (Amariglio et al., 2012; Merrill et al., 2012), tau neurofibrillary tangles (Merrill et al., 2012), hippocampal volume (Szabo et al., 2011), and olfactory dysfunction (Sohrabi et al., 2009). The MFQ is composed of four subscales measuring perceived frequency of forgetting, seriousness of forgetting, retrospective functioning (difference of current memory abilities from those earlier in life), and mnemonics usage, respectively. Each question is rated on a 7-point Likert scale, with higher scores indicating more favorable levels of perceived memory functioning (e.g., fewer

SMCs). However, for the sake of clarity, we calculated each individual's score as a percentage and then subtracted it from one, such that higher reported values correspond to higher SMC levels. Because scores pertaining to mnemonics usage were uncorrelated with the other three subscales in both this and previous work (Amariglio et al., 2012), questions comprising this subscale were excluded from participants' MFQ scores. Cronbach's alpha for the remaining three subscales ranged from .92–.96 in this study, which are similar to those reported in formal validations of the MFQ (Gilewski et al., 1990). Cronbach's alpha after collapsing across the three subscales was .97, and each subscale was significantly correlated with each of the others (r 's > .21, p 's < .05).

Memory Self-Efficacy—Memory self-efficacy was assessed using the Memory Controllability Inventory (MemCo; Lachman, Bandura, Weaver, & Elliott, 1995), a 12-item survey that evaluates older adults' beliefs about the controllability of their memory abilities with age. Each question is rated on a 7-point scale, with higher values indicating higher levels of perceived controllability. The MemCo contains four subscales measuring present ability, potential improvement, effort utility, and inevitable decrement, respectively. The MemCo differs importantly from the MFQ in that, with the exception of the present ability subscale, the MemCo assesses general beliefs about memory (e.g., "There are things that I can do to keep my memory from declining.") rather than perceived memory abilities. Test-retest reliabilities of .50–.65 and .46–.57 have been obtained for the MemCo after periods of nine days and three months, respectively (Lachman et al., 1995). Because the present ability subscale was designed to assess the same construct as the MFQ, these questions were excluded from analysis. Cronbach's alpha for the MemCo was .90 and .87 before and after excluding the present ability subscale, respectively, suggesting that exclusion of this subscale did not appreciably reduce the internal consistency of this measure. Cronbach's alpha for the remaining three subscales ranged from .72–.77, similar to those previously reported (Lachman et al., 1995). Each subscore was significantly correlated with each of the others (r 's > .55, p 's < .001).

Anxiety and Depression—Anxiety and depression were assessed using the Hospital Anxiety and Depression Inventory (HADS, Zigmond & Snaith, 1983; see also Bjelland, Dahl, Haug, & Neckelmann, 2002; Michopoulos et al., 2008; Mykletun, Stordal, & Dahl, 2001). The HADS is a 14-item questionnaire assessing symptoms of depression (7 questions) and anxiety (7 questions). Each question is rated on a 4-point Likert scale, with higher values indicating higher levels of depression and anxiety. This questionnaire has demonstrated high concurrent validity with other common anxiety and depression assessments, such as the Beck Depression Inventory and the State-Trait Anxiety Inventory, and has shown a 20-day test-retest reliability of .94 (Michopoulos et al., 2008). Cronbach's alpha was .87 for the entire survey, .84 for the anxiety subscale, and .75 for the depression subscale. These values are similar to those reported in formal validations of HADS (e.g., Mykletun et al., 2001).

Note that a large majority of our participants' scores suggested sub-clinical symptom levels. A score of .38 on either the anxiety or depression subscales of HADS has been suggested as

a cutoff for caseness (Bjelland et al., 2002). Seven participants met this cutoff for either subscale, and the findings did not change when these participants were excluded.

Cognitive Tasks—Participants completed several standard neuropsychological tests assessing multiple cognitive domains. These tasks include the Mini Mental State Examination (MMSE-2; Folstein, Folstein, & McHugh, 1975), as well as the Trail Making Tests A and B (Reitan, 1958) and the Digit Symbol Substitution Test (DSST) from the Wechsler Adult Intelligence Scale III (Wechsler, 1997a). Of particular interest were scores from two standard delayed recall tests, the Logical Memory and Word Lists Recall sections of the Wechsler Memory Scale III (Wechsler, 1997b). For these tests, participants listened to readings of two brief stories (for Logical Memory) or lists of 12 words (for Word Lists). Participants recalled everything that they could remember immediately after each listening. Recall was tested again after a delay of ~30 minutes. Delayed recall scores corresponded to the number of story elements (out of a possible 50) or words (out of a possible 12) recalled after the delay.

A spatial reconstruction task similar to that described in Watson et al. (2013) was also administered. During this task, participants viewed a series of displays presented on a computer screen, each of which contained five novel abstract line drawings presented in a different spatial configuration. Participants were given 20 seconds to study each display, followed by a 4 second delay in which a blank screen was presented. A self-paced reconstruction test was then completed in which the five items from the preceding study display appeared at the top of the screen, and participants used a mouse to click and drag each object in an attempt to reconstruct the original display as veridically as possible. Participants completed four blocks of five displays each, for a total of 20 displays. For two included participants, data from one of the four blocks were unusable due to a data logging error, so these participants' performance was calculated based on the remaining three blocks. Participants' eye positions were recorded throughout this task using an EyeLink 1000 eye tracking system (SR Research, Ontario Canada). Eye tracking data are not considered in the present report. Participants completed six practice trials prior to beginning the task.

Reconstruction accuracy was quantified using two metrics—swap errors and item misplacement—that differ in the demands that they place on relational memory. Swap errors refer to situations in which a pair of objects is transposed in space, as would be expected due to failures of item-location binding. The proportion of swap errors committed by each participant was operationalized as the number of times the signs of both the X and Y coordinates of the vector comprising the spatial relationship between two objects were reversed. A change in the X sign denotes a reconstruction error that alters the horizontal (left-right) relationship between two objects, whereas a change in the Y sign indicates an error that reverses the vertical (top- bottom) relationship. A swap error requires both errors to be present simultaneously for a pair of items, as would occur if an object that was originally located above and to the right of another was placed below and to its left at reconstruction. Swap errors are fundamentally relational and have previously demonstrated exquisite sensitivity to hippocampal integrity (Monti et al., 2015; Pertzov et al., 2013; Watson et al., 2013).

Misplacement error was calculated as the distance in pixels between the geographic centers of each item's studied and reconstructed location. Misplacement error has historically been the most common measure used to assess spatial reconstruction (Huttenlocher & Presson, 1979) and is also affected by hippocampal damage, though to a lesser degree than swap errors (Pertsov et al., 2013; Watson et al., 2013). Figure 1 contains an illustration of each error type.

Measures of raw misplacement and swap error rates are highly mathematically dependent on one another given that some forms of error contribute to more than one metric. In particular, swap errors generally also result in high misplacement values, since they necessarily entail the misplacement of two items. Thus, we conducted analyses using a measure of "swap-corrected" misplacement, in which we excluded stimuli that were involved in a swap error on each trial and re-calculated misplacement error for that trial based on the remaining items. Trials containing more than one swap error were excluded entirely, because only two or fewer of the five stimuli would have been able to contribute to misplacement analyses on such trials. On average, 16 trials per participant were included in our misplacement metric (range = 9–20 trials).

Experimental Procedures

Data from each participant were collected over two visits averaging 8 days apart (range = 2–24 days). On the first visit, participants completed the MFQ and two cognitive tasks not considered in the present report. Participants were given copies of the HADS and MemCo to complete in between laboratory visits. On the second visit, participants completed the battery of neuropsychological tests followed by the spatial reconstruction task.

Data Analysis

Thirteen participants declined or neglected to answer one of the fifty-six questions comprising the MFQ, and two participants' data were missing more than one question (maximum missing = 3). In addition, one participant each had missing data on the MemCo and HADS measures. To account for missing data, participants' scores were calculated as a proportion of the maximum score possible given the number of questions answered. This procedure is mathematically equivalent to computing prorated scores, in which each participant's missing item(s) are imputed with that participant's mean response to completed items. The high internal consistencies exhibited by all three measures support the use of this approach to missing data. Moreover, all analyses were repeated using only participants with no missing data to verify that this method of imputation had no effect on the findings.

Data from the MMSE, Trail Making Tests, DSST, Logical Memory Delayed Recall, and Word Lists Delayed Recall were converted to z-scores and then averaged for each participant so as to create a composite neuropsychological performance score. For the Trail Making Tests, the dependent measure used was the difference between the time taken to accurately complete Test B and that taken to accurately complete Test A. These composite scores were used to exclude participants with the lowest cognitive performance (see "Participants", above).

We conducted correlational analyses to test for associations between participants' SMC scores and the four measures of memory (i.e., number of words recalled in the delayed word

recall task, number of story elements recalled in the delayed story recall task, proportion of swap errors made during the spatial reconstruction task, and mean misplacement error per trial made during the spatial reconstruction task). In addition, we correlated SMCs with levels of anxiety, depression, and memory self-efficacy. A Bonferroni-corrected p -value of .007 served as the threshold for significance. Guided by these results, we then performed hierarchical multiple regression analyses to investigate the individual and combined abilities of specific measures to account for variance in participants' SMCs.

RESULTS

Correlational analyses

Table 2 depicts a correlation matrix for all variables of interest. As shown, age and education were significantly correlated with multiple measures of interest. Thus, all subsequently-reported correlations were run with these two variables included as covariates (e.g., partial correlations), such that reported values represent the relationship between SMCs and each variable of interest with age and education held constant. These corrected scatterplots are depicted in Figure 2. SMCs correlated negatively with MemCo scores [$r(68) = -.40$, $p = .001$], indicating that individuals with higher levels of memory concerns also expressed lower memory self-efficacy. Correlations between SMCs and anxiety and depression did not meet the corrected threshold for significance (r 's = .24 and .16, p 's = .04 and .20 respectively), though both anxiety and depression correlated significantly with MemCo scores (r 's = $-.40$ and $-.41$; p 's = .001). While SMCs were numerically associated with worse performance on all four measures of memory, only the correlation with swap errors reached significance [$r(68) = .36$, $p = .002$]. MemCo scores were not correlated with any measure of memory performance, nor were depression or anxiety (p 's > .11).

Hierarchical linear regression models of SMCs

We next used hierarchical linear regression analyses to examine whether swap errors accounted for unique variance in SMCs beyond that accounted for by delayed recall. The results are depicted in Table 3a. Age and education data were entered in the first step of a regression model predicting SMCs, resulting in significant explained variance [$R^2 = .19$, $F(2,69) = 7.69$, $p = .001$, $f^2 = .23$]. Delayed word and story recall scores were entered in a second step, which was non-significant [$R^2 = .05$, $F(2,67) = 2.30$, $p = .11$, $f^2 = .07$]. Importantly, a third step containing swap errors accounted for significant residual variance [$R^2 = .07$, $F(1,66) = 6.68$, $p = .01$, $f^2 = .10$]. Table 3b indicates that when the order of entry of swap errors and delayed recall scores was reversed, swap errors again accounted for significant variance in SMCs [$R^2 = .11$, $F(2,68) = 10.37$, $p = .002$, $f^2 = .16$], and the residual variance accounted for by delayed recall was non-significant [$R^2 = .01$, $F(2,66) = 0.70$, $p = .50$, $f^2 = .01$].

These regression analyses provided converging evidence that the sensitivity of swap errors to SMCs can augment that of traditional metrics of delayed verbal recall. Interestingly, the relationship between swap errors and SMCs appears to be independent of the observed relationship of SMCs to memory self-efficacy, as evident by a non-significant correlation between swap errors and MemCo scores [$r(68) = -.15$, $p = .23$]. Two additional regression

models were conducted to further assess the independence of these predictors. The results are depicted in Table 4. After accounting for age and education in step 1, swap errors again accounted for 11% of residual variance. Entering MemCo scores in a third step accounted for an additional 10% of variance [$F(1,67) = 10.79, p = .002, f^2 = .17$], bringing the total explained variance to 40% (see Table 4a). Table 4b illustrates that the results did not change appreciably when the order of entry of swap errors and MemCo scores was reversed, again suggesting that relational memory and self-efficacy independently predicted SMCs.

Mediation analyses: Indirect effects of SMCs on negative affective symptoms

Although correlations between SMCs and depression and anxiety were non-significant, significant negative correlations emerged between both depression and anxiety and MemCo scores (see Table 2). Taken together with the robust correlation obtained between MemCo scores and SMCs, these data suggest that memory self-efficacy may mediate the relationship between SMCs and negative affective symptoms. We formally tested for such an effect using the INDIRECT mediation analysis program (Preacher & Hayes, 2008), which uses bootstrapping and confidence intervals to estimate the reliability of indirect effects. HADS scores provided a composite measure of depression and anxiety, and age and education were included as covariates. The direct effect of SMCs on HADs was nonsignificant when controlling for MemCo [$\beta = .07, se = 0.17, p = 0.70$]. By contrast, the 95% bias-corrected confidence intervals for the indirect effect of SMCs on HADs mediated by MemCo did not contain zero [$\beta = .24, se = 0.09, CI = 0.10\text{--}0.48$], indicating a significant indirect effect. A path diagram for this analysis is depicted in Figure 3. To test an alternative model in which HADS mediates the relationship between SMCs and MemCo, an analysis was performed in which HADS was entered as the mediator and MemCo as the dependent variable. The indirect effect of SMCs on MemCo mediated by HADS approached, but did not differ from zero [$\beta = -0.10, se = 0.06, CI = -0.23\text{--}0.001$], providing additional support for a conceptualization of memory self-efficacy as a mediator of the relationship between SMCs and negative affective symptoms.

DISCUSSION

The rapid expansion of the older population globally has brought cognitive aging to the forefront of public health concern (e.g., Cutler, 2015). This increased attention and awareness can be beneficial, particularly in light of recent progress in identifying lifestyle modifications that may slow memory decline if implemented sufficiently early (Institute of Medicine, 2015). However, the present study and others (Jessen et al., 2007) indicate that concerns about memory decline can have multiple, distinct precipitating factors that must be disentangled before the appropriate intervention(s) can be prescribed. Here we identified two relatively independent “profiles” of SMCs. One profile was associated with impairments in specific aspects of memory performance, whereas the second was linked to low levels of memory self-efficacy, or perceived levels of controllability of memory outcomes with age.

Associations between SMCs in healthy older adults and performance on standard neuropsychological tests have been weak or nonexistent in many previous studies (Balash et al., 2010; Bartley et al., 2012; Brucki & Nitrini, 2009; Hohman et al., 2011; Jessen et al.,

2006; Jorm et al., 2004; Kim, 2013; Minett et al., 2008; Reid & MacLulich, 2006; Saykin et al., 2006; Slavin et al., 2010; Stewart et al., 2008, 2011; Striepens et al., 2010; van der Flier et al., 2004; but see Amariglio et al., 2012; Jessen et al., 2007; Szabo et al., 2011). Our results were broadly consistent with this prior work, in that performance on two neuropsychological tests of delayed recall exhibited modest correlations with SMCs that were reduced to marginal significance after controlling for age and education. However, we were able to establish a more robust correlation between SMCs and cognitive performance by virtue of a measure that was chosen to selectively assess relational memory integrity—namely, the number of times participants “swapped” or reversed the relative positions of items during a spatial reconstruction task. In addition to these correlational findings, a series of hierarchical regression models revealed that the swap metric was able to account for unique variance in SMCs beyond that accounted for by age, education, and delayed recall performance.

As previously mentioned, the hippocampus and its surrounding cortical regions are a primary target of preclinical AD pathology (Braak & Braak, 1991). An extensive body of evidence suggests that a loss of hippocampal integrity can lead to selective relational memory impairments, and that swap errors are a particularly sensitive index of hippocampal function (e.g., Monti et al., 2015; Pertzov et al., 2013; Watson et al., 2013). SMCs have likewise been linked to AD-related biomarkers in healthy older adults (Amariglio et al., 2012; Jessen et al., 2006; Merrill et al., 2012; Saykin et al., 2006; Stewart et al., 2008; Striepens et al., 2010; van der Flier et al., 2004), and have been associated with the subsequent development of dementia (Donovan et al., 2014; Jessen et al., 2010; Luck et al., 2010; van Oijen et al., 2007). Together, these data suggest that cognitive measures with strong relational processing demands may facilitate the identification of individuals with early neuropathology. The present data contribute importantly to this body of evidence by demonstrating a behavioral relationship between relational memory errors and SMCs. Of course, future studies that measure SMCs, swap errors, and relevant biomarkers concurrently will be required to directly assess these brain-behavior relationships, as well as their relationship to psychosocial facets of SMCs such as self-efficacy (which will be further discussed below). Nonetheless, these results support the potential for relational memory assessments to serve as tools to corroborate perceived memory impairments, particularly in situations wherein access to relevant biomarkers is limited.

As a caveat, in theory there are several differences between the swap error metric and the delayed recall tasks aside from their relational memory processing demands that could have contributed to their differential relationship to SMCs. Many of these differences, such as the modality of the stimulus presentation, the delay between study and test, and the visual versus verbal nature of the stimuli, can be accounted for by our misplacement metric, which was derived from the same task using the same stimuli but which did not correlate with SMCs. However, the present data cannot refute the possibility of another explanation. For example, an examination of the standard deviation of each measure relative to its mean (e.g., the coefficient of variation, which assesses the variance of a measure independent of scale) suggests that the overall variance of swap errors exceeded that of the other three memory metrics, a factor that may have contributed to its ability to more closely track the continuous measure of SMCs. Future research should certainly pursue a range of possible methods for

improving the sensitivity of current neuropsychological tests to SMCs—including variance-based improvements—in addition to further investigating the prognostic and diagnostic potential of relational memory measures.

We must also emphasize that we are not suggesting that delayed recall be abandoned or replaced as a diagnostic tool, particularly given its long history of facilitating successful diagnoses of age-related neurodegenerative disorders. Indeed, although SMCs are prevalent in cognitively healthy older adults, they also tend to accompany more overt cognitive deficits that are detectable using traditional neuropsychological batteries. Significant correlations between SMCs and delayed recall performance have likewise been found in prior studies that have included a wide range of performance on these and other neuropsychological tests (e.g. Snitz, Morrow, Rodriguez, Huber, & Saxton, 2008; see also Supplemental Table 2 for converging evidence from the lowest-performing individuals in our sample). The added value of measures that are highly selective to relational memory may thus be greatest in individuals with higher levels of overall cognitive performance (Cook & Marsiske, 2006; Saykin et al., 2006). Interestingly, it is this population for whom SMCs also seem to be most strongly associated with reduced hippocampal volumes (van Norden et al., 2008) and with the subsequent development of dementia (van Oijen et al., 2007). These findings have been attributed to a particular need for more sensitive cognitive measures in due to a tendency toward ceiling effects and/or a greater awareness of subtle cognitive changes on the part of higher-performing older adults.

Higher levels of SMCs were associated with lower levels of memory self-efficacy in our participants, a finding that replicates previous research (Mol et al., 2008). However, the present study is the first to our knowledge to provide evidence of independent contributions of self-efficacy and memory performance to SMCs. Moreover, our data suggest that there may be unique health implications associated with harboring SMCs in conjunction with low levels of memory self-efficacy. Specifically, we found statistical support for a model by which self-efficacy mediates the relationship between SMCs and anxiety and depression. Said differently, these analyses suggest that older adults with higher levels of memory self-efficacy may be less likely to experience heightened negative affect when faced with perceived memory failures than are older adults with lower levels of self-efficacy, perhaps because high-efficacy individuals are more confident in their abilities to develop strategies to compensate or counteract age-related memory decline. Of course, longitudinal research and/or experimental manipulations of self-efficacy will be required to confirm a causal model. Nonetheless, the notion that self-efficacy can influence individuals' affective responses to perceived memory decline is provocative, particularly in light of evidence that stress and depression can contribute to cognitive aging (Bunce, Batterham, Christensen, & Mackinnon, 2014; Kremen et al., 2012) and promote dementia pathology (Rothman & Mattson, 2010; Sotiropoulos et al., 2008). Accordingly, the potential for interventions that focus on self-efficacy (e.g., Lachman et al., 1992; West et al., 2008) to act upon this pathway by tempering affective responses to perceived memory decline warrants further attention.

An additional important question is whether SMCs serve as a chronic or prolonged stressor in older adults with low memory self-efficacy, or whether this pathway is better characterized as an acute negative response to memory challenges or perceived memory

failures. The present data cannot differentiate among these possibilities. All participants completed the MFQ, MemCo, and HADS after being made aware that they were participating in a memory study. Moreover, as described in the Experimental Procedures, additional memory testing was administered in between the time that participants completed the MFQ and their subsequent completion of the MemCo and HADS. We thus cannot determine whether these or other aspects of our experimental procedures may have affected participants' questionnaire responses in a manner that temporarily magnified the relationships among these constructs, or, on the contrary, whether the mediational relationship depicted in Figure 3 would hold even without proximity to an experiment or other cognitively challenging situation. These questions should be investigated in future research, particularly given that they may inform the type of interventions best suited to reducing negative psychosocial consequences of SMCs.

As a caveat, the absence of significant associations between memory self-efficacy and memory performance in the present study should not be taken as evidence that these variables are unrelated in all circumstances. On the contrary, several published studies provide evidence that self-efficacy can have a facilitative effect on cognitive performance across the lifespan, particularly by way of goal-setting, strategy use, and responsiveness to training opportunities (Berry & West, 1993; Lachman & Andreoletti, 2006; Payne et al., 2012). We also do not mean to suggest that low levels of self-efficacy should be entirely unrelated to the likelihood that preclinical AD pathology is present in older individuals with SMCs. Rather, the present data indicate that self-efficacy in and of itself is a construct that warrants assessment (and intervention when necessary) as part of a comprehensive effort to address memory concerns in older adults in a manner that will maximize both cognitive outcomes and overall quality of life.

Finally, the present research is limited by its relatively small and homogeneous sample, which was primarily white, female, and highly educated. Higher education levels in particular have been linked to a greater prognostic value of SMCs with respect to subsequent AD (van Oijen et al., 2007). Thus, additional research is called for to determine whether the selective relationship of SMCs to relational memory performance reported here generalizes to other populations. Additionally, the cross-sectional nature of this research precludes our ability to link SMCs to recent changes in relational memory performance, which are arguably more prognostically informative than is performance at any one point in time. Nonetheless, the present data provide insight into the absence of associations between SMCs and objective memory performance found in previous cross-sectional studies by highlighting the importance of choosing sufficiently sensitive cognitive outcome measures, while also affirming a key role of psychosocial screening instruments in probing the origins of SMCs. Together, these tools promise to inform appropriate responses within the medical community to the widespread and growing public concerns surrounding age-related memory decline.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
Sample trial from spatial reconstruction task.

Figure 2.

Scatterplots of partial correlations between subjective memory concerns (SMCs) and key variables of interest after controlling for age and education. The values on the X and Y axes represent the residual values after regressing age and education on the variable associated with each axis. A) Correlations between SMCs and swap errors (upper left), misplacement error (upper right), delayed story recall (lower left) and delayed word recall (lower right). B) Correlations between SMCs and depression (upper left), anxiety (upper right), and memory self-efficacy (lower left).

Figure 3.
Path diagram of the total and direct effects of subjective memory concerns (SMCs) on anxiety and depression, as well as the indirect effects of SMCs with memory self-efficacy included as a mediator.

Table 1

Descriptive statistics for included study participants (n = 72). MFQ = Memory Functioning Questionnaire; MMSE = Mini Mental State Examination; Neuropsych Composite = composite neuropsychological score; SR = spatial reconstruction; MemCo = Memory Controllability Index; HADS = Hospital Anxiety and Depression Survey

Variable	Mean	(SD)	Min – Max
Age (years)	66.57	(3.79)	61 – 78
Female	72.2%	-	–
1–3 years of college or more	91.7%	-	12 th grade – PhD/equivalent
Race	–	-	–
Asian	6.9%	-	–
Black	8.3%	-	–
White	84.7%	-	–
MFQ	0.29	(0.10)	0.06 – 0.54
MMSE	28.82	(1.04)	26 – 30
Trail Making Test A (sec)	31.13	(9.36)	15.00 – 62.41
Trail Making Test B (sec)	67.88	(25.65)	25.25 – 166.03
Digit Symbol Coding	67.79	(13.33)	31 – 95
Logical Memory - Delayed	33.19	(5.22)	21 – 43
Word Lists Recall - Delayed	8.64	(2.05)	4 – 12
Neuropsych Composite	0.28	(0.43)	–0.54 – 1.15
SR swap errors	0.08	(0.04)	0.00 – 0.18
SR misplacement error	160.24	(32.43)	103.15 – 262.82
MemCo	0.76	(0.12)	0.27 – 1.00
HADS Depression	0.16	(0.15)	0.00 – 0.76
HADS Anxiety	0.17	(0.14)	0.00 – 0.76

Table 2

Correlation matrix depicting associations among variables of interest.

	SMCs	Age	Education	Logical Memory	Word Lists	Swap Errors	Mis Error	HADS- Depress	HADS- Anxiety	MemCo
SMCs	—	.08	-.43***	-.29*	-.26*	.43***	.16	.23	.27*	-.42***
Age		—	-.26*	-.13	-.17	.27*	.35**	.03	-.05	.18
Education			—	.26*	.18	-.30*	-.10	-.21	-.10	.16
Logical Memory				—	.36**	-.47***	-.37**	.12	.16	.10
Word Lists					—	-.28*	-.16	.04	-.10	.16
Swap Errors						—	.60***	.09	-.04	-.13
Mis Error							—	.01	-.06	.02
HADS Depress								—	.69***	-.43***
HADS Anxiety									—	-.42***
MemCo										—

SMCs = subjective memory concerns; Mis Error = spatial reconstruction misplacement error; HADS = Hospital Anxiety and Depression Survey; MemCo = Memory Controllability Index.

* p < .05;

** p < .01;

*** p < .001

Table 3

Summary of hierarchical regression models predicting subjective memory concerns (SMCs) based on age, education, and memory performance. A) Model with delayed recall entered before swap errors. B) Model with swap errors entered before delayed recall.

A) Delayed Recall Entered Before Swaps			
	Beta	R² Change	R² Total
Step 1 – Age and Education		0.19 **	0.19
Age	-.04		
Education	-.44 ***		
Step 2 – Delayed Recall		0.05	0.24
Age	-.07		
Education	-.39 **		
Word Lists	-.15		
Logical Memory	-.14		
Step 3 – Swaps		0.07 *	0.31
Age	-.12		
Education	-.34 **		
Word Lists	-.12		
Logical Memory	-.02		
Swaps	.31 *		
B) Swaps Entered Before Delayed Recall			
	Beta	R² Change	R² Total
Step 1 – Age and Education		0.19 **	0.19
Age	-.04		
Education	-.44 ***		
Step 2 – Swaps		0.11 **	0.30
Age	-.11		
Education	-.36 **		
Swaps	.35 **		
Step 3 – Delayed Recall		0.01	0.31
Age	-.12		
Education	-.34 **		
Swaps	.31 *		
Word Lists	-.12		

B) Swaps Entered Before Delayed Recall

	Beta	R ² Change	R ² Total
Logical Memory	-.02		

*
p < .05;

**
p < .01;

p < .001

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Table 4

Summary of hierarchical regression models predicting subjective memory concerns (SMCs) based on age, education, swap errors, and memory self-efficacy (MemCo). A) Models with swap errors entered before self-efficacy. B) Models with self-efficacy entered before swap errors.

A) Swaps entered before MemCo			
	Beta	R² Change	R² Total
Step 1 – Age and Education		0.19 **	0.19
Age	-.04		
Education	-.44 ***		
Step 2 – Swaps		0.11 **	0.30
Age	-.11		
Education	-.36 **		
Swaps	.35 **		
Step 3 – MemCo		0.10 **	0.40
Age	-.02		
Education	-.30 **		
Swaps	.30 **		
MemCo	-.33 **		
B) MemCo entered before swaps			
	Beta	R² Change	R² Total
Step 1 – Age and Education		0.19 **	0.19
Age	-.04		
Education	-.44 ***		
Step 2 – MemCo		0.13 **	0.32
Age	.05		
Education	-.36 **		
MemCo	-.37 **		
Step 3 – Swaps		0.08 **	0.40
Age	-.02		
Education	-.30 **		
MemCo	-.33 **		
Swaps	.30 **		

* p < .05;

**
p < .01;

p < .001

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