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Exploring Cognitive Effects of Self Reported Mild Stroke in Older Adults: Selective but Robust Effects on Story Memory

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Abstract

Relatively little systematic information is available regarding patterns of cognitive effects of mild stroke in older adults. We explored this problem with a series of two independent samples from the Victoria Longitudinal Study data archives. In Study 1, self-reported mild stroke and neurologically intact matched controls were (a) confirmed as similar on a set of neurocognitive speed, basic cognition, and awareness indicators, and (b) compared for differences on a set of episodic, semantic, and working memory tasks. The mild stroke group was selectively worse on the language intensive story memory task. This effect was partially attributable to a deficit in remembering the most thematic information. Study 2 closely replicated these procedures and results. In addition, Study 2 follow-up analyses, comparing provisional right-hemisphere damaged and left-hemisphere damaged (LHD) participants, revealed that the thematic story memory deficit for mild stroke participants could be due to the selective impairment of LHD participants.

Keywords

Mild stroke; Aging; Story memory; Language; Left hemisphere damage; Right hemisphere damage

INTRODUCTION

Stroke is the leading cause of neurological disability among adults (Ahmed, Ness, Howard, & Aronaw, 2005; Fujiura & Rutkowski-Kmitta, 2001; Lyden, 1996), with associated behavioral sequelae ranging from the functional (e.g., cognitive, motor) to the clinical (e.g., quality of life, depression) (e.g., Narushima, Chan, Kosier, & Robinson, 2003; Tatemichi, Desmond, Stern, Paik, Sano, & Bagiella, 1994). Although 70% of incident stroke patients experience some degree of post-stroke cognitive impairment (Kase, Wolf, Kelly-Hayes, Kannel, Beiser, & D'Agostino, 1998), the extent and determinants of post-stroke cognitive decline are associated with multiple factors, including severity and location of the lesion and assorted demographic factors such as age and education. Aging is a major risk factor for stroke (e.g., Babikian, Kase,

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& Wolf, 1994). Although severe strokes receive the bulk of therapeutic and research attention, mild strokes, which often reflect silent or asymptomatic lesions, are thought to be the most common gradation of stroke in older adults (Jørgensen, Nakayama, Raaschou, Pedersen, Houth, & Olsen, 2000; Schmidt, Roesler, Kretschmar, Ladwig, Junker, & Berger, 2004). Nevertheless, more information about sequelae of mild stroke is necessary.

Among the issues to clarify for the growing population of mild stroke older adults are (a) the range and specificity of cognitive or motor effects, (b) underlying neurological damage (including hemispheric differences), (c) clinical diagnosis and prognosis, (d) possible relationship to other vascular sources of cognitive impairment, and (e) neurorehabilitation and productivity prospects (e.g., Bach-y-Rita, 2001; Musicco, Emberti, Nappi, & Caltagirone, 2003; Prins et al., 2005). At present, stroke management programs are targeted to moderate-to-severe cases, partly because mild cases are relatively under-reported, under-documented, and incompletely resolved (see Srikanth et al., 2003). We explore one of these issues, namely, the potential cognitive sequelae of self-reported mild stroke in older adults.

Mild stroke may be characterized by the same neurological factors used to document and measure neurological damage in severe stroke. These factors include location, size, temporal sequence, and mechanism (Hom & Reitan, 1990). However, in the absence of severe and prototypical cognitive and motor symptoms, adults experiencing a mild stroke may present to a clinician with (a) a variety of minor or selective symptoms and (b) relatively little neurological or specific stroke information (Schmidt et al., 2004). Such untreated and nonspecific mild strokes may not be associated with clearly identifiable or diagnostic, patterns of cognitive, language, and motor impairments (Leskelä et al., 1999; Wahlin, 2004). Moreover, the time course for resolution may differ by patient and function. In contrast, severe stroke may be associated with several serious subsequent decrements, including Alzheimer's disease (AD) and vascular dementia (e.g., Pohjansvaara, Erkinjuntti, Vataja, & Kaste, 1997; Srikanth et al., 2004; Tatemichi et al., 1992), as well as global and specific impairments (e.g., Hochstenbach, Mulder, van Limbeek, Donders, & Schoonderwaldt, 1998; Tatemichi et al., 1994). With otherwise healthy older adults, specific (and lingering) impairments resulting from mild stroke may be masked by, or attributed to, normal aging-related cognitive declines or to the cognitive effects of preclinical neurodegenerative or other vascular processes (Prins et al., 2005).

Although little is known about the cognitive sequelae of mild stroke, some guidelines for the present research come from studies of both severe (e.g., Srikanth et al., 2003) and mild or silent (e.g., Schmidt et al., 2004) stroke. First, severe stroke is related to diminished performance on global cognitive functioning (such as that measured by the MMSE), memory (Beeson, Bayles, Rubens, & Kaszniak, 1993; Stewart, Sunderland, & Sluman, 1996), speed of information processing (Hochstenbach et al., 1998; Leskelä et al., 1999), attention (Korda & Douglas, 1997; McDowd, Filion, Pohl, Richards, & Stiers, 2003), executive function (Leskelä et al., 1999), and language processing (Ferstl, Guthke, & von Cramon, 1999; Titone, Wingfield, Caplan, Waters, & Prentice, 2001). Silent (asymptomatic) stroke has recently been associated with impairments in cognitive domains, at least relative to everyday movement or life skills (Schmidt et al., 2004). Second, the magnitude of the stroke effect is moderated by such neurological factors as location, size, and temporal sequence of the cerebrovascular event. However, the brain-injury-behavior effects are less charted and more complex, especially considering the underlying heterogeneity in cortex structure and organization, variability in brain function in older adults, irregularity in brain damage after injury, and increasing cognitive variability and inconsistency with normal and impaired aging (e.g., Dixon et al., 2007; Ferstl et al., 1999; Hultsch & MacDonald, 2004; Shammi, Bosman, & Stuss, 1998). Groups of untreated mild stroke patients are unlikely to be homogenous neurologically, demographically, or cognitively. Third, silent and mild strokes are associated with relatively shorter periods of neurological and functional recovery (Jørgensen, Nakayama, Raaschou, Vive-Larsen, Støier,

& Olsen, 1995). Although some recovery can be expected within the first 6 months following a mild stroke, full functional recovery may take several years (Greveson, Gray, French, & James, 1991; Hewer, 1990). Complicating the goal of understanding sequelae of mild stroke is the fact that individuals may be on different recovery trajectories (Duncan, Wallace, Lai, Johnson, Embretson, & Laster, 1999; Larson, Kirschner, Bode, Heinemann, Clorfene, & Goodman, 2003).

We focus on possible non-aphasic language and memory deficits, processes potentially affected by mild stroke. Understanding and remembering the main points of everyday experiences, conversations, and instructions are crucial to re-entering or adapting to post-stroke work and social lives. Notably, in normal cognitive aging, such skills remain adaptive and generally preserved into late life. For example, remembering everyday narratives is relatively spared in late life, as is the correlated skill of identifying and recalling the themes and main ideas of everyday discourse (e.g., Dixon et al., 2004). Evidence regarding these adaptive cognitive-language skills is less clear for adults with different forms of brain injuries (e.g., Brookshire & Nicholas, 1984; Ferstl et al., 1999; Heath & Blonder, 2005; Hough, 1990; Titone et al., 2001; Tun & Wingfield, 1997), including mild stroke injuries (e.g., Stewart et al., 1996; Sunderland, Tinson, & Bradley, 1994).

We use replicated case control procedures, as they have been used effectively in clinical studies on stroke effects (e.g., Brookshire & Nicholas, 1984; Srikanth et al., 2003; Tatemichi et al., 1994). Typically, the clinical and control groups are matched on the basis of simple demographic characteristics (e.g., age, gender) and compared on an outcome measure such as global cognition (e.g., Kase et al., 1998). Mild stroke and normal controls may differ on a variety of underlying neurocognitive and cognitive measures and these, too, may contribute to individual or group differences in specific and higher-order performances. For example, group differences in complex memory tasks may be associated with individual differences in strategy use, working memory capacity, or basic neurocognitive speed of information processing (e.g., Hultsch, Hertzog, Dixon, & Small, 1998). Given that many older adults and mild stroke patients may be largely unaware of neurobiological details of the cerebrovascular event, developing a behavioral profile of expected cognitive similarities and deficits may prove both theoretically salient and clinically relevant. Moreover, given the heterogeneity of injured (and intact) cortex structure and organization in older adults, even the presence of lesion information would not necessarily imply specific cognitive sequelae. Arguably, for mild stroke, cognitive-behavioral information may be more readily available and useful than neurobiological information.

Notably, we present two fully independent case-control studies, with the second designed as a replication and extension of the first. The participants are taken from two independent samples of older adults who fit the following profile: (a) community-dwelling adults over age 55, (b) participants in a large-scale study on aging, (c) self-reporting the first experience of a recent mild stroke, (d) presenting with little diagnostic information, (e) having received modest or undocumented medical attention for their stroke, but (f) able to complete all concurrent project-related activities and testing. We use the data archives of the Victoria Longitudinal Study (VLS; Dixon & de Frias, 2004) to implement the following four research phases in each of the two studies. First, we identified two sets of recent mild stroke patients, from different VLS samples, as based on health self-reports at intake. Second, we selected two sets of well-matched controls for each stroke group on the basis of three demographic background variables (i.e., age, gender, education). Third, we compared the stroke and control groups in each study on a series of behavioral measures spanning the continuum from neurocognitive resources (e.g., speed of information processing) to cognitive performance to metacognitive awareness (e.g., self-initiated compensatory actions). This unique phase was designed to produce an additional form of classification criteria that, if satisfied, could render subsequent experimental comparisons more compelling. Fourth, we compared the stroke and control groups in each study on

experimental indicators of episodic, semantic, and working memory. Based on previous literature, we reasoned that memory tasks involving language processes might be most sensitive to group differences. The overall goal is to begin with a simple self-report indicator of mild stroke status and then to build a detailed case regarding the evidence for spared and differentiable cognitive skills in adults recovering from a mild stroke.

STUDY 1

Method

Participants—Three independent samples of community-dwelling adults (initially aged 55–85 years) are followed in the Victoria Longitudinal Study (VLS), an on-going sequential study of biomedical and cognitive aging (Dixon & de Frias, 2004). VLS recruitment procedures provide for initially healthy samples, with exclusionary criteria including history or presence of serious cardio/cerebrovascular, neurological, and psychiatric illnesses. Present data were selected from the first two samples of the VLS. Whereas the initial wave of testing for Sample 1 was conducted in 1986–1987 ($n = 484$), the first wave of testing for Sample 2 occurred in 1992–1993 ($n = 530$). For both samples the interval between waves was 3 years. The reasons for attrition for both samples were typical for longitudinal studies: They include busy or lack of interest, moved, personal illness, and death (for further information see Hultsch et al., 1998). At each interval, all returning participants are volunteers, ambulatory, and non-institutionalized.

A comprehensive intake interview (at each wave) includes a series of questions about changes in health conditions during the intervening 3 years. For Study 1, we selected all VLS participants from Sample 1 (Wave 2) and Sample 2 (Wave 1) who reported having previously experienced a mild stroke. In the two-part question, participants first indicated whether a stroke had occurred and, second, evaluated the seriousness of the stroke as mild or severe. No participant reported experiencing a severe stroke. Although no independent medical information about the stroke is available, recent studies have shown that such self-report measures of stroke incidence can be reliable and accurate (Horner, Cohen, & Blazer, 2001; see also Schmidt et al., 2004). After the first phase of stroke case identification, each stroke participant was used to select the best available match from the healthy (no stroke) VLS participant pool (from the same sample) on age, gender, and education. In addition, no participant in either group reported other neurological, cardiovascular, or psychiatric conditions. Because of the large VLS data base for these two samples, excellent matching for each stroke case was achieved in this second phase.

Overall, the subsample for this study comprised $n = 48$ participants ($n = 24$ reporting previous mild stroke; $n = 24$ controls with no history of stroke) who ranged in age from 63 to 83 years (both groups: $M = 73.4$, $SD = 6.5$). There were $n = 18$ women and $n = 6$ men in each group. Groups were successfully matched on years of education (stroke: $M = 13.3$ years, $SD = 3.1$; controls: $M = 13.6$ years, $SD = 2.2$). As a follow-up to the matching, we examined self-reported general health for the two groups. Two indicators—comparing overall health to a perfect state and to other people at the same age—were used. On average, participants from both groups rated their health as being good on both 5-point scales, in which 0 indicated very good health (perfect state: $M_s = 1.2$, $.75$; $SD_s = .87$, $.53$; same age: $M_s = 1.00$, $.46$; $SD_s = .88$, $.51$; for stroke and controls, respectively). Unsurprisingly, controls reported a slightly better view of their own health than did stroke participants, but the latter did not view themselves as otherwise unhealthy.

Measures—After sample selection and matching, we began the third phase of the research. We explored the extent to which the two groups were comparable on a selected set of verbal (but not memory-based) neurocognitive (speed), cognitive (comprehension), and awareness

(memory compensation) measures (for further information about each measure see Dixon & de Frias, 2004; Hultsch et al., 1998). The purpose was to confirm indirectly that the reported stroke was relatively mild and not neurologically deeply disruptive. The specific tests were reading time (Hultsch, Hertzog, & Dixon, 1990), comprehension time (Masson, 1983), lexical decision time (Baddeley, Logie, Nimmo-Smith, & Brereton, 1985), semantic decision time (Palmore, Busse, Maddox, Nowlin, & Siegler, 1985), memory compensation strategy use (de Frias & Dixon, 2005; Dixon, de Frias, & Bäckman, 2001), and reading comprehension (Hultsch et al., 1998). The fourth phase of the study was the experimental component, in which the two groups were compared on a battery of verbal and language-based memory measures (see description below).

Word Recall: Six categorized lists of common English nouns were drawn from the Howard (1980) and Battig and Montague (1969) norms. Each list contained six words from each of five taxonomic categories for a total of 30 words per list. Categories and exemplars were selected to minimize potential interference effects within and between lists. In general, high-frequency exemplars ranked two through nine were chosen to minimize guessing. The most frequently used noun was not used. Participants had 2 min to study the words from each of two lists, followed immediately by a 5-min written recall test for each list. Participants were instructed to write down as many of the words as possible in any order. Parallel forms reliability of the word lists is reported as averaging at .64 across three times of measurement (Hultsch et al., 1998). In addition, five measures of qualitative recall were derived (Dixon et al., 2004; Halper & Cherney, 2004): (a) number of categories [as an indirect indicator of the retrieval of superordinate organizational units (see Tulving & Pearlstone, 1966)]; (b) average number of words recalled per category (as an indirect index of retrieval of subordinate units, given retrieval of the superordinate unit), (c) number of intrusions (words from the category that were not on the list), (d) number of repeated words [as a measure of online monitoring of memory functioning (Koriat, Ben-Zur, & Sheffer, 1988; Stuss, Craik, Sayer, Franchi, & Alexander, 1996)]; and (e) categorical organization or semantic clustering of words recalled (using Adjusted Ratio of Clustering, ARC; Roenker et al., 1971).

Story Recall: Six narrative stories were taken from a set of 25 parallel stories (Dixon, Hertzog, Friesen, & Hultsch, 1993). Each story described an event in the life (lives) of an older protagonist, who was a woman (two stories), a man (two stories), or a couple (two stories). The structurally equivalent and well-organized stories consisted of 24 sentences and contained approximately 300 words, organized into approximately 160 propositions (Dixon et al., 1993; Kintsch, 1974). Each participant studied and recalled two stories which were presented in typed booklets. Participants were given 4 min to study each story and then 10 min to write their recall. Participants were instructed to recall as much of the substance of the story as possible, including the main ideas and details. They were told that they could recall the story in their own words, those of the story, or both. Parallel forms reliability of the stories is reported as averaging at .73 across three times of measurement (Hultsch et al., 1998). For scoring, the template text base is compared to a participant's recall protocol (Turner & Green, 1978). Gist recall of the propositions (idea units) in the texts was used as a measure of quantity of recall (see Dixon et al., 1993). One qualitative performance indicator of story recall performance was included. The original propositional analyses include a numerical indicator (based on expert judges' ratings) of the position of each proposition in the hierarchy of information in each story (see Dixon et al., 1993). The ratings ranged from Level 1 (main ideas) to Level 5 (specific details). To use this qualitative indicator in this study, no additional scoring was required.

Fact Recall: A total of 240 general-information questions were selected from those developed by Nelson and Narens (1980). Six sets of 40 questions were sorted to equate the sets roughly in terms of content (e.g., science, art) and difficulty as indexed by the Nelson and Narens norms. Participants were given two sets of questions. The task was self-paced. Reliability estimates

were derived by computing the correlation between scores on the two sets of questions. The correlations for these alternate forms are reported as averaging at .84 across three times of measurement (Hultsch et al., 1998).

Reading Span: Salthouse's (Salthouse & Babcock, 1991) reading span task involved having participants answer a simple question about each of a series of sentences while retaining the last word of each sentence for later recall. The sentences were presented orally by the experimenter at a normal reading rate. A simple question about the sentence appeared in a printed test booklet, and individuals chose the answer from one of three presented alternatives. Once all sets of sentences were presented, participants were asked to write down the target words (last word of each sentence) in their order of presentation. The number of sentences in a series ranged from one to seven, and three trials were given at each series length. The score reflects the highest span (number of sentences) on which correct recall of the target words occurred on at least two of the three trials. The reliability of this task based on split-half correlations by the Spearman–Brown formula was .86 in two different samples (Salthouse & Babcock, 1991).

Computational Span: Salthouse's (Salthouse & Babcock, 1991) computational span task involved having participants solve a series of simple arithmetic problems while retaining the last digit of each problem for later recall. The problems were presented by the experimenter at a normal speaking rate. The problems were simple addition or subtraction problems composed of single digit numbers. Participants chose the answer to the problem from among three alternatives printed in a test booklet. At the end of a series of problems, participants were asked to write down the target numbers (last digit of each problem) in order. The number of problems in a series ranged from one to seven, and three trials were given at each series length. The score was the highest span (number of problems) on which correct recall of the target numbers occurred on at least two of the three trials. The split-half reliability of this task is reported as ranging from .84 to .90 across two samples (Salthouse & Babcock, 1991).

Procedure—All measures used in this study were administered during three sessions lasting approximately two hours each. Further information on the testing procedure of the VLS is available elsewhere (Dixon & de Frias, 2004; Hultsch et al., 1998).

Analyses—For all the analyses, alpha levels of $p \leq .05$ were specified to indicate statistical significance. Two sets of analyses were conducted. For Phase 3, a series of one-way within-subjects analyses of variance (ANOVA) with group (stroke, control) as the within-subjects factor were conducted for each of the comparison criteria. For Phase 4, a series of one- and two-way within-subjects ANOVAs, as well as analyses of covariance (ANCOVA), were conducted on the memory measures: Group and thematic levels (for story recall) were the principal factors, and memory span was tested as a covariate. Within-subjects ANOVAs were conducted as a function of case-control procedures.

Results

Phase 3: Group Comparisons on Cognitive Resources and Awareness—For each of the six one-way within-subjects ANOVAs on the Phase 3 analyses, the group (stroke, control) factor did not reach statistical significance. The null results indirectly confirm the overall prediction that the mild stroke group would perform similarly to their healthy controls on a continuum of basic neurocognitive resources and cognitive awareness indicators (Table 1).

Phase 4: Group Comparisons on Memory Performance—For word recall, no group differences were observed in the number of words recalled (stroke: $M = 16.46$, $SD = 5.55$;

control: $M = 16.65$, $SD = 4.37$). In addition, the main effect for group was not significant for any of the qualitative indicators of word recall, indicating that the processes they represent are not differentially affected by mild stroke (see Table 2).

For story recall, as measured by the average proportion of the total propositions recalled, a main effect for group was significant, $F(1, 23) = 9.70$, $p < .01$, $\eta^2 = .30$, with the stroke ($M = .26$, $SD = .10$) performing lower than the control ($M = .35$, $SD = .11$) group. A second ANOVA determined whether the group effect generalized across all hierarchical levels of information. The 2 (group) $\times$ 5 (thematic level) within-subjects ANOVA revealed a main effect for level, $F(4, 92) = 11.73$, $p < .001$, $\eta^2 = .26$, and a significant group $\times$ thematic level interaction, $F(4, 92) = 49.56$, $p < .001$, $\eta^2 = .14$. This interaction is depicted in Figure 1. *Post hoc* comparisons revealed that both groups recalled more main ideas (Level 1) than intermediate levels (Levels 2 through 4) and details (Levels 5–7) of the stories. The overall pattern was consistent with previous research with healthy older adults (e.g., Dixon et al., 2004) in that recall was highest for the main ideas and lowest for the details of stories. Notably, however, the control group significantly outperformed the stroke group in recall of propositions at the higher thematic levels (i.e., Levels 1 and 2).

For fact recall, no significant group differences were observed (stroke: $M = 17.28$, $SD = 6.24$; control: $M = 18.50$, $SD = 6.94$). For working memory, we examined group differences on the non-verbal and verbal tasks separately, observing a similar trend for better performance by the control participants. Although group performance was not significantly different for the computational span performance (stroke: $M = 2.43$ problems, $SD = 1.24$; control: $M = 3.04$ problems, $SD = 1.37$), it was significant for the reading span, $F(1, 22) = 6.64$, $\eta^2 = .77$ (stroke: $M = 2.22$ sentences, $SD = .90$; control: $M = 2.87$ sentences, $SD = 1.08$).

Given that working memory capacity has an effect on episodic memory functioning in normal aging (e.g., Hultsch et al., 1998), and we observed group differences in story memory, we added reading span as a covariate to determine whether group effects in story recall were affected by limitations in verbal working memory. To explore this question, the analyses were conducted in two ways, with reading span entered as either a continuous or a dichotomous (high, low) variable for both average story recall and thematic level. The results were mixed. For average story recall, the main effect of group was no longer significant, but the continuous covariate was significant, $F(1, 44) = 6.21$, $\eta^2 = .12$. In contrast, with a dichotomous covariate, the main effect of group remained significant, $F(1, 44) = 5.74$, $\eta^2 = .12$, but the covariate was not significant. For thematic level, the original effect for Levels continued to be significant for the continuous, $F(1, 41) = 7.10$, $\eta^2 = .41$, and dichotomous, $F(1, 44) = 6.38$, $\eta^2 = .13$, covariate. Notably, the original group $\times$ thematic level interaction remained significant when the covariate was entered both as a continuous, $F(1, 41) = 3.88$, $\eta^2 = .28$, and as a dichotomous, $F(1, 41) = 3.88$, $\eta^2 = .27$, variable. In both instances, the thematic level $\times$ covariate interaction was not significant. Overall, the pattern suggests the potential for a reading span measure of working memory to serve as a mediator for the effect of stroke on story recall, although the influence may be subtle.

Discussion

After identifying both mild stroke and matched control participants from the VLS database, we confirmed that the matching procedure had produced comparable groups in terms of performance on a series of pertinent neurocognitive resource and cognitive strategy indicators. As expected, we observed no group differences on any of the neurocognitive and cognitive indicators. One implication of this finding is that a common clinical indicator of severe stroke (i.e., a deficit in speed of information processing) may not apply to mild stroke, at least not to older adults for whom some degree of recovery may have occurred and in whom an informal sense of having returned to active life may have emerged. However, normalized performance

on speed indicators may not indicate complete recovery of function, as they do not necessarily recover in lockstep with—much less determine—more complex cognitive skills. Another potential implication is that the sequence of recovery from mild stroke may include relatively early repair, restoration, or compensation for the minor neurological damage incurred in the cerebrovascular incident. This hypothesis must await longitudinal data, either from later waves of the VLS or prospective studies (e.g., Roth & Lovell, 2003), as well as data pertaining to location and severity of the neurological injury (presently unavailable in the VLS).

Two other measures included in this pre-experimental phase merit brief attention. The reading comprehension measure did not produce group differences, indicating perhaps that language differences for recovering mild stroke adults may be more memory-related than simply understanding-based. Awareness was indicated by responses to the Memory Compensation Questionnaire (MCQ), a multi-factor instrument measuring one's awareness of memory deficits and efforts to overcome them through a variety of compensatory techniques. The MCQ has been used in normal older adult, memory impaired, and AD samples (e.g., Dixon et al., 2001; Dixon & de Frias, 2007; Dixon, Hopp, Cohen, de Frias, & Bäckman, 2003) but not previously in stroke patients. Although no differences were observed between the two groups, the MCQ may not specifically target the kind of memory deficits potentially present in vascular or mild stroke patients (as compared perhaps to severe stroke or memory-impaired patients).

In the experimental phase we examined the following basic research question: Is there a generalized loss in memory, or is it differential across systems of memory, or is it even more selective within a system? Somewhat generalized sparing was indicated in that no group differences were observed for word recall (including both quantitative and qualitative indicators), fact recall (a semantic task), and computation span (a working memory task). Whether the absence of group differences reflects preserved functioning (relatively unaffected by the mild stroke) or recovered functioning (relatively rapid recovery of performance in these memory domains) can not be determined in these data.

Nevertheless, this apparent memory sparing did not apply to the language-based episodic task, story recall. The group effect for overall story recall, but not word list recall, suggests that episodic tasks requiring more complex operations may be the most sensitive to mild stroke. Speculatively, it may be that the ability to navigate a narrative is sufficiently complex that large areas of cortex are involved. If relatively simpler memory tasks involve more restricted cortical regions, this could diminish the probability that a lesion (from a mild stroke) would affect memory performance. However, story recall performance may involve such distributed areas of cortex that the probability is increased that a mild stroke would affect performance. If the complexity of the operations involved in reading and remembering stories is responsible for detecting subtle differences between older adults with and without an incident of mild stroke, a more direct indicator of the processing of the complexity of a story should be illuminating.

Indeed, we observed a main effect for recall performance as organized by thematic level, a variable that reflects the hierarchical structure of a narrative. As is often the case for normal older adults (e.g., Dixon et al., 2004), we found that a generally greater proportion of main ideas than details were recalled from the original story, a pattern typically interpreted favorably. That is, identifying and recalling the main ideas of a story can produce a well-structured re-telling of the narrative. In contrast, re-telling a narrative with a greater proportion of details than main ideas can produce an ill-structured story. In research using participants with more serious brain damage than our mild stroke participants, the hemisphere in which the damage occurs plays a role in the relative production of main vs detailed ideas (e.g., Titone et al., 2001). Not known yet is whether the present differential pattern reflects disproportional representation of right- or left-hemisphere damage in the stroke group. It is clear, however, that verbal memory for language-based tasks is not spared in mild stroke (or it takes longer to

recover) relative to verbal memory for less complex tasks. Thus, episodic memory—a hallmark indicator of decline due to normal aging and preclinical AD alike—may be differentially affected by mild stroke. Speculatively, the sparing on word memory (simpler) in the context of selective losses in story memory (more complex) may be clinically indicative of mild stroke damage rather than a neurodegenerative disease.

The significant group difference for the reading working memory task underscores our focus on memory for language even in the context of verbal materials (as in word recall) or similar processing demands (as in the computation working memory task). Noting that working memory plays an intermediate role in the prediction of episodic memory in normal older adults (e.g., Hultsch et al., 1998), we followed this result by incorporating this measure as a covariate in story memory analyses. Although not definitive, the results confirm the general interpretation that everyday language-intensive tasks may be especially promising indicators of lingering mild stroke effects. Neurorehabilitation for mild stroke victims may benefit from the knowledge that narrative processing remains a subclinical challenge, even in the absence of word list memory deficits. Clinical attention might be directed to skills in remembering and re-telling narratives, especially identifying the themes of the story. The source and implications of the effects of reading span must be explored further. Unavailable at present in the VLS, but useful for future research, would be pre-morbid indicators of key processes and any post-stroke treatment.

Our exploration of cognitive effects of mild stroke has pointed to language-based memory tasks as a selected impairment. Several strengths and limitations in our research design were noted above. One additional limitation is that the stroke group was relatively small. Given the promising patterns and results, and the limitations of diagnosis and group size, a replication and extension study is advisable. Accordingly, we initiated a second study using an independent VLS sample. In Study 2, we identified a new set of mild stroke participants (and matching controls) from a different VLS sample, replicated the above memory results, and investigated the possible moderating effect of hemisphere damage (Schmidt et al., 2004).

STUDY 2

The main results of Study 1 showed that stroke participants may identify and recall fewer main ideas of a story compared to healthy matched controls. A subsequent question is whether right-hemisphere damaged (RHD) and left-hemisphere damaged (LHD) participants differ in their performance on these measures and, especially, whether differential performance contributes to the patterns observed in Study 1. Important for the purposes of the present study are previous findings that some aspects of language processing, and perhaps especially story memory, differ as a function of lesion laterality (e.g., Vanlancker-Sidtis, 2004). In particular, LHD participants have consistently been shown to recall fewer main ideas in comparison to RHD or control participants (Gardner, Brownell, Wapner, & Michelow, 1983; Webster, Godlewski, Hanley & Sowa, 1992). In contrast, the patterns of findings for RHD participants have been mixed. Some studies have found RHD participants recall fewer main ideas relative to controls (e.g., Gardner et al., 1983; Titone et al., 2001), whereas other studies have found that RHD participants do not have impairments in recalling the main ideas of stories (Webster et al., 1992). In addition, other tasks, seemingly similar in cognitive demands (e.g., joke production or comprehension; Heath & Blonder, 2005), show different patterns.

The present objectives were: (a) to replicate Study 1 findings with a new and independent case-control sample, and (b) to explore whether story memory performance differs as a function of lesion laterality. We examined provisional hemispheric differences in performance using additional information that was collected in the VLS Sample 3 (Wave 1) intake health questionnaire. We expected to replicate the Study 1 recall findings. Based on previous research

(e.g., Gardner et al., 1983; Webster et al., 1992), we expected that LHD participants will recall fewer main ideas than do RHD participants.

Method

Participants—Study 2 used VLS participants from Sample 3 (Wave 1) who reported having had a stroke. The Sample 3 intake questionnaire requested the participants to evaluate the severity of their stroke, with three possible classifications (mild, moderate, severe). No severe strokes were reported. Of the participants indicating a sub-severe stroke, 70.8% reported a mild stroke and 29.2% reported a moderate stroke. Because of limited group size, and primary interest in sub-severe stroke, both mild and moderate cases were classified together. Mean age of onset of stroke was 68.52 years ($SD = 10.80$, range = 47.5–87.0). Time since stroke was uncorrelated with 24 of 26 indicators of cognitive performance (exceptions: one aspect of story recall, one memory compensation scale). Each stroke participant was matched to a healthy VLS control from Sample 3 (Wave 1) on gender, age, and education. Overall, there were $n = 48$ participants ($n = 24$ who reported having had a stroke and $n = 24$ controls with no history of stroke in their lifetime) who ranged in age from 57 to 90 years (stroke: $M = 75.50$ years, $SD = 8.82$; controls: $M = 75.38$ years, $SD = 8.62$). The matching process was successful. There were $n = 9$ women and $n = 15$ men in each group. Average education level was similar for the two groups (stroke: $M = 14.13$, $SD = 4.17$; control: $M = 14.25$, $SD = 3.29$). All participants were fluent in English and right-handed (stroke participants were right-hand dominant prior to stroke). Following matching, the groups were compared on two health self-ratings (i.e., overall health relative to a perfect state; health relative to other people of the same age) measured on a 5-point scale, in which 0 indicated very good health. Both groups rated their health as being good on both scales (perfect state: $M_s = 2.38, 1.92$; $SD_s = .82, .72$; same age: $M_s = 2.17, 1.42$; $SD_s = .82, .58$; for stroke and controls, respectively).

For the stroke participants, the laterality of the stroke was inferred from a self-report questionnaire developed and implemented as part of intake for VLS Sample 3. The question set reflected (a) elementary facts about brain organization as they are related to (b) typical clinical and easily accessible effects of mild stroke (e.g., language, movement, sensation deficits). Participants were sorted into provisional categories of right-hemisphere damage (RHD) or left-hemisphere damage (LHD) from their reports of having experienced the following conditions related to their stroke and, where applicable, which side of the body was affected: (a) language problems, (b) loss of feeling in any part of the body, (c) loss of movement in any part of the body, and (d) difficulty seeing or attending to objects on one side of the body. Those classified as RHD indicated at least one impairment on the left side of their body; the reverse is true for those who were classified as having LHD. Ten RHD and five LHD participants were identified, with the majority of both groups indicating a mild stroke. (We were unable to verify location for nine participants.) RHD and LHD participants ranged in age from 57 to 87 years (RHD: $M = 71.90$, $SD = 9.07$; LHD: $M = 80.20$, $SD = 6.06$). Mean age of onset of stroke for RHD participants was 64.95 years ($SD = 9.56$) and for LHD participants was 74.00 years ($SD = 9.17$). RHD and LHD groups had similar levels of education (RHD: $M = 13.50$, $SD = 4.03$; LHD: $M = 13.60$, $SD = 2.88$). There were seven women and three men in the RHD group; the LHD group was comprised entirely of men (i.e., $n = 5$).

Measures—Again, the third phase of the study involved comparing the stroke and control groups on a set of verbal, neurocognitive, cognitive, and awareness measures. Phase 4 involved comparing the stroke and control, and RHD and LHD, groups on episodic, semantic, and working memory measures. All measures used in Study 1 were also used in the present study.

Procedure—The same procedure outlined in Study 1 was followed in the present study.

Analyses—For all analyses, alpha levels of $p < .05$ were specified to indicate statistical significance. Four sets of analyses were conducted: (a) for Phase 3, a series of one-way within-subjects ANOVAs with group (stroke, control) as the within-subjects factor were computed on each of the comparison measures, (b) a series of one-way between-subjects ANOVAs with group (RHD, LHD) as the between-subjects factor were performed on each of the comparison measures, (c) for Phase 4, a series of one- and two-way ANOVAs, with group (stroke, control) as the within-subjects factor, were conducted on the memory measures, and (d) a series of one- and two-way between-subjects ANOVAs with group (RHD, LHD) as the between-subjects factor were performed on the memory measures.

Results

Phase 3: Group Comparisons on Cognitive Resources and Awareness—Study 1 results were replicated, in that no significant differences were found between the stroke and control groups on the basic cognitive speed and awareness measures (Table 3), with the exception of reading time [$F(1, 22) = 4.78, p < .05, \eta^2 = .18$]. Control participants ($M = 1163.70$ ms, $SD = 446.48$) had longer reading times relative to stroke participants ($M = 934.96$ ms, $SD = 277.52$). The overall similarities of performance are interpreted as indirect evidence that the stroke was indeed relatively mild and not deeply disruptive to their long-term cognitive functioning. As a check, we also compared RHD and LHD participants, and they did not significantly differ on any of the basic cognitive measures. For the awareness measures, only one of the MCQ scales produced a significant laterality effect; namely, the scale measuring the extent to which individuals recruit others for everyday memory assistance [$F(1, 13) = 7.76, p = .02, \eta^2 = .37$]. Specifically, LHD participants ($M = 1.64, SD = 1.00$) reported recruiting others more than did RHD participants ($M = .70, SD = .32$). The overall findings suggest that RHD and LHD groups had similar levels of cognitive functioning. Given that the age difference between the RHD ($M = 71.90$ years, $SD = 9.07$) and LHD ($M = 80.20$ years, $SD = 6.06$) groups approached significance [$F(1, 13) = 3.36, p = .09$], all of the analyses on the basic cognitive measures were re-done using age as a covariate. Specifically, a series of between-subjects Analyses of Covariance (ANCOVA) with group (RHD, LHD) as the between-subjects factor were computed on each of the basic cognitive measures. These analyses revealed that the RHD and LHD groups did not differ on any of the basic cognitive measures. Furthermore, the RHD-LHD group difference in MCQ recruitment of others disappeared after controlling for age.

Phase 4: Group Comparisons on Memory Performance—Stroke and control groups did not significantly differ on the total number of words recalled (stroke: $M = 15.52, SD = 4.92$; control: $M = 14.54, SD = 4.75$), or on any of the qualitative indicators (Table 4). For fact recall, no significant differences were observed between the stroke ($M = 20.56, SD = 6.89$) and control ($M = 18.63, SD = 7.21$) groups.

For story recall, no significant difference was found between the stroke and control groups on the average proportion of propositions recalled. To address whether the groups differed in recall of propositions at different hierarchical levels of the texts, a 2 (group) $\times$ 5 (thematic level) ANOVA, with both factors as within-subjects factors, was computed on proportion of propositions recalled. The main effect of thematic level was significant, $F(4, 92) = 53.91, p < .001, \eta^2 = .42$, as was the group $\times$ thematic level interaction, $F(4, 92) = 2.68, p < .05, \eta^2 = .02$ (see Figure 2). *Post hoc* comparisons indicated that both stroke and control groups recalled significantly more main ideas (Level 1) compared to intermediate levels (Level 2) and details (Levels 5–7) of the stories. The control group also recalled more main ideas than did the stroke group, but there were no group differences at the lower levels.

The two groups were compared on both reading and computational span. No significant group differences were observed for either reading span (stroke: $M = 2.79$ sentences, $SD = 1.10$;

control: $M = 2.50$ sentences, $SD = .98$) or computational span (stroke: $M = 2.87$ problems, $SD = .85$; control: $M = 2.88$ problems, $SD = 1.33$). Consequently, no further analyses were conducted on these measures.

RHD-LHD Comparison on Memory Performance—The RHD and LHD groups did not differ on any of the quantitative (RHD: $M = 16.95$ words, $SD = 4.38$; LHD: $M = 11.90$ words, $SD = 5.48$) or qualitative indicators of word recall. These results were confirmed even after controlling for age in a between-subjects ANCOVA with group (RHD, LHD) as the between-subjects factor.

For story recall, RHD and LHD groups did not significantly differ on the average proportion of propositions recalled (RHD: $M = .36$, $SD = .09$; LHD: $M = .29$, $SD = .03$). A between-subjects ANCOVA with group (RHD, LHD) as the between-subjects factor and age as a covariate confirmed that the groups did not differ on the average proportion of propositions recalled. A 2 (group) $\times$ 5 (thematic level) ANOVA, with group as the between-subjects and thematic level as the within-subjects factor, revealed significant main effects for both group [RHD: $M = .44$, $SD = .15$; LHD: $M = .30$, $SD = .09$, $F(1, 13) = 7.80$, $p < .05$, $\eta^2 = .10$] and thematic level [$F(4, 52) = 12.54$, $p < .001$, $\eta^2 = .31$]. As shown in Figure 3, a significant group $\times$ thematic level interaction was also found, $F(4, 52) = 4.25$, $p < .01$, $\eta^2 = .11$. *Post hoc* comparisons revealed that the RHD group recalled significantly more main ideas than intermediate levels (Level 2) or details of the story (Levels 5–7). In contrast, the LHD group did not differ in their recall of main ideas, intermediate levels, or details of the stories. Finally, the RHD group recalled significantly more main ideas compared to the LHD group, but the two groups did not differ at the lower levels. We computed a 2 (group) $\times$ 5 (thematic level) ANCOVA, with group as the between- and thematic level as the within-subjects factor, and age as the covariate, on proportion of propositions recalled. Nonsignificant main effects of both group and thematic level were observed. The group $\times$ thematic level interaction remained significant after controlling for age, $F(4, 48) = 3.56$, $p < .05$, $\eta^2 = .23$. *Post hoc* comparisons revealed the same pattern of recall for the groups across the levels.

The RHD group was compared to their matched healthy controls on story recall. A 2 (group) $\times$ 5 (thematic level) ANOVA, with both factors as within-subjects factors, was computed on the proportion of propositions recalled. The main effect of level was significant, $F(4, 36) = 38.39$, $p < .001$, $\eta^2 = .53$. *Post hoc* comparisons indicated that both the RHD group and their matched controls recalled significantly more main ideas (Level 1) compared to intermediate levels (Level 2) and details (Levels 5–7) of the stories. No other significant differences were found.

For fact recall, no significant differences were found between the groups (RHD: $M = 20.15$, $SD = 6.46$; LHD: $M = 20.10$, $SD = 7.37$). The ANCOVA computed controlling for age confirmed that the groups did not differ on fact recall. The RHD and LHD groups were compared on reading and computational span. These analyses revealed that the groups did not differ in reading span (RHD: $M = 2.80$ sentences, $SD = 1.23$; LHD: $M = 3.00$ sentences, $SD = 1.41$) or computational span (RHD: $M = 2.60$ problems, $SD = .70$; LHD: $M = 2.80$ problems, $SD = 1.30$). Moreover, the ANCOVAs performed controlling for age revealed that the groups did not differ on either of these measures. No further analyses were performed on these measures.

Discussion

The two main objectives to Study 2 involved replication and extension: (a) to determine whether the interesting episodic memory (especially story recall) findings of Study 1 would be replicated in an independent group of older adults, and (b) to follow-up these results by examining provisional hemispheric differences in the language-based task of story memory.

As in Study 1, virtually no group differences were found on the behavioral measures from Phase 3. Now replicated, this null result can tentatively be interpreted as indicating that typical speed and awareness measures do not adequately distinguish between recovering mild stroke victims and well-matched controls. However, it is still possible that such tasks could discriminate between individuals with mild versus severe strokes.

Study 1 and Study 2 produced quite consistent results in Phase 4. In both studies we observed virtually no group differences in semantic or working memory performance and the same selective effects in the episodic memory tasks. Specifically, the story memory task produced overall group differences, and in both studies these effects were qualified by selective deficits on the part of the stroke group in remembering the main ideas of the story. These results are consistent with those observed in similar studies by other researchers (e.g., Brookshire & Nicholas, 1984; Titone et al., 2001). This replicated result underscores the credibility of the speculative explanation based on language task complexity (see Study 1). Namely, because of the complexity of the story memory task a larger cortical region may be recruited for its performance, thus maximizing the probability that even a minor lesion (associated with mild stroke) could affect performance. Also replicated were the results pertaining to a complexity index (i.e., the hierarchical organization of the recall protocols).

One exception to the consistent patterns in Studies 1 and 2 was the comparison of reading span performance. Whereas in Study 1, control participants performed better than the stroke group, in Study 2 there was no significant effect. No clear interpretation for this minor difference is apparent, but it is possible that the two stroke groups differ marginally in the process represented by this task, due to uncontrolled aspects of their strokes (severity, location), recovery periods, or even diurnal inconsistency. As noted earlier, some diversity is expected in mild cases of neurological injury or disturbance, and this is no less true for mild stroke than for mild forms of cognitive impairment (e.g., Dixon et al., 2007).

A second goal was to explore the extent to which the results might be influenced by hemispheric differences in injury. Although it has long been apparent that both cerebral hemispheres are involved in the understanding of, and communication through, narrative language (e.g., Brownell, Simpson, Bihle, Potter, & Gardner, 1990), a growing body of reports have documented behavioral deficits associated with RHD and LHD patients (e.g., Halper & Cherney, 2004). RHD and LHD stroke participants performed similarly across the cognitive tasks. The differences between these two groups were again isolated to the most language-intensive task, story memory. Interestingly, the LHD group recalled significantly fewer main ideas of the stories than did the RHD group. This result not only clarifies earlier stroke-control comparisons, but it is consistent with some previous findings. For example, one study by Gardner and colleagues (1983) revealed that RHD patients recalled significantly more main ideas of stories than did LHD patients. Similar results showing an LHD deficit in recall of main ideas relative to RHD patients was observed in a study by Webster et al. (1992). In a related functional magnetic resonance imaging (fMRI) study, Caplan and Dapretto (2001) showed that the left hemisphere was used to detect the gist of the topic of conversation and the organization and logic of conversational narratives. Moreover, another fMRI study showed that the left hemisphere was more prominent as readers process propositional information at the onset of the story, suggesting that damage to this region may restrict the ability of patients to detect the themes of narratives, at least insofar as they are foreshadowed or presented early in the reading of the text (Xu, Kemeny, Park, Frattali, & Braun, 2005). Finally, two recent studies with related language materials (e.g., metaphors) have reported that left hemisphere damage may be associated with deficits in processing close (not distant) semantic relationships (Schmidt, DeBuse, & Seger, 2007), as well as conventional and salient (not novel and nonsalient) metaphoric meanings (Mashal, Faust, & Hendler, 2005).

Despite this convergence of results, we highlight a potential limitation in our procedure. We required participants to write their recall on paper. Perhaps such fine motor task demands could have differentially delimited the available evidence for the LHD group's memory performance. That is, because of contralateral crossover in the brain, LHD participants may have experienced motor deficits in the right side of their body, which could have affected their writing performance (all participants were right-hand dominant prior to stroke), and consequently the amount of recall they produced. However, such a possibility can be qualified, if not ruled out, by three considerations. First, the fact that the LHD participants were able to provide written recall of as many details of the stories as RHD participants suggests that the LHD participants did not have a (serious) motor deficit in their right arm to hinder their writing performance. Secondly, as a check for group differences in handwriting-related fine-motor skill (i.e., copying speed), we compared RHD and LHD participants on the speed of their performance for copying both familiar and unfamiliar stimuli (see Dixon, Kurzman, & Friesen, 1993, for more information on this technique). The groups did not differ in the number of characters produced within a given time interval across several trials, an observation supporting the original interpretation. Third, the Gardner et al. (1983) and Webster et al. (1992) studies used an oral recall procedure, but found the same results. They also found that, whereas the RHD group recalled more main ideas than details, the LHD group showed a relatively flat pattern of sensitivity to, and recall of, the thematic levels of the story. Overall, following a mild stroke, LHD participants may be impaired in identifying and recalling the main ideas of stories compared to RHD participants and, of course, control older adults.

Conclusion

To date, most research on cognitive consequences of stroke has focused on the effects of severe strokes as opposed to mild or moderate stroke. The prevalence estimates of mild stroke cases are substantial and likely to increase as the population of older adults expands. Therefore, further research on this topic has both theoretical and practical implications (Schmidt et al., 2004). The results from our two studies converge on the following conclusion: Older adults who reported having experienced a mild stroke are at risk for selective but enduring deficits in specific aspects of language-based episodic memory. A key aspect of processing narratives is the extent to which an observer (reader) can distinguish between thematic and non-thematic (detail) information and balance the resulting (or recalled) story in a way that enhances its communicative value. The healthy older adults displayed their skill at selectively identifying and recalling main ideas from the present narratives, revealing a pattern consistent with some other research (Dixon et al., 2004). In contrast, the older adults who had experienced a mild stroke were comparatively impaired in this regard. Moreover, in Study 2, we were able to tentatively isolate this deficit to those older adults who were LHD. Such a pattern converges with recent evidence from the behavioral and neurobiological levels (e.g., Caplan & Dapretto, 2001).

Although the present results are empirically robust and theoretically interpretable, several limitations should be noted. First, the two mild stroke groups consisted of individuals who were at various points in their recovery and who had little current medical information about their injury or its immediate aftermath. Future research will benefit from more formal information regarding neuropathological evidence (pertaining to various sources and characteristics of mild stroke), medical characteristics (e.g., standardized severity ratings, other known or unknown vascular conditions) and rehabilitation responses (e.g., treatment or scans). Although self-reports of stroke information have been validated (Horner et al., 2001; see also Schmidt et al., 2004), more detailed information (about incidence, severity, and date) would be preferred. Nevertheless, the relative lack of information about mild stroke may actually represent the most typical scenario facing clinicians when first presented with possible mild stroke cases. Second, one notable advance of Study 2 was the new self-report data pertaining

to possible lesion location. Although the results shed light on the subtleties of the story memory deficit, more precise procedures (e.g., imaging) for confirming and delineating the location of the lesion – on a finer grain than left/right hemisphere—would be welcome for future research (e.g., Ances & D’Esposito, 2000). Notably, however, systematically executed self-report procedures can produce reasonable information pertaining to presence, severity, and general location of mild stroke.

Third, the present case-control studies featured two independent mild stroke groups, as well as two well-matched control groups. Nevertheless, some aspects of the sampling frame may limit the generalizability of the results. The present stroke groups are not active clinical cases, in that no individual was presently receiving treatment for stroke, and all had volunteered (and performed) the extensive testing involved in the VLS protocol. Therefore, we do not know whether other cognitive deficits could have been detected earlier in the process of recovery. In addition, the volunteer VLS samples may be fairly advantaged in some demographic respects (Hultsch et al., 1998). At present, we have no information about the extent to which demographic or social advantages may confer some neuroprotection or reserve for recovering from mild brain injuries, but it is an issue worth exploring (Stern, 2006).

Despite these limitations, the results of two exploratory studies show robust convergences in results. Certainly, the idea of exploring additional and more detailed aspects of sequelae of mild stroke is encouraged. Given the characteristics of the VLS samples, the present stroke participants and upcoming incident cases are likely to provide substantial evidence pertaining to the risk factors for mild stroke, as well as a broadening range of cognitive, language, and productivity consequences.

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FIGURE 1.
Group differences in recall across levels of information in Study 1.

FIGURE 2.

Study 2: Although similar in pattern across levels of information, the stroke group recalled fewer main ideas than control group.

FIGURE 3.

Study 2: Selective deficit of main idea recall by LHD but not RHD group.

TABLE 1

Means (Standard Deviations) for cognitive resources and awareness measures for stroke and control groups in Study 1

Measure	Group		<i>p</i>
	Stroke	Control	
Reading comprehension	19.59 (5.04)	20.95 (4.74)	.39
Reading time	1120.05 (399.83)	1052.86 (322.00)	.53
Comprehension time	30441.70 (16678.64)	25819.63 (11333.04)	.27
Lexical decision time	1455.41 (1144.05)	1103.68 (316.53)	.19
Semantic decision time	4087.09 (2002.13)	3465.82 (904.17)	.21
Memory compensation questionnaire			
External aids	3.10 (.80)	3.41 (.54)	.16
Internal mnemonics	2.20 (.77)	2.26 (.66)	.77
Time investment	2.02 (.86)	2.07 (.63)	.83
Recruitment of others	1.43 (.78)	1.48 (.90)	.84
Effort investment	2.54 (.95)	2.78 (.67)	.28
Success/Commitment to memory	2.23 (.81)	2.23 (.97)	.97
Awareness of changes in compensation	2.47 (.46)	2.49 (.50)	.93

TABLE 2

Means (Standard Deviations) for word recall for stroke and control groups in Study 1

Measure	Group		<i>p</i>
	Stroke	Control	
Total number words recalled	16.46 (5.55)	16.65 (4.37)	.88
Number of categories recalled	4.52 (.76)	4.69 (.36)	.25
Mean words recalled per category	3.29 (1.11)	3.33 (.88)	.90
Number of intrusions	.14 (.14)	.15 (.17)	.87
Number of repeated words	.15 (.35)	.13 (.22)	.80
Clustering	.63 (.36)	.70 (.20)	.44

TABLE 3

Means (Standard Deviations) for cognitive resources and awareness measures for stroke and control groups in Study 2

Measure	Group		<i>p</i>
	Stroke	Control	
Reading comprehension	21.52 (3.87)	22.48 (4.46)	.43
Reading time	934.96 (277.52)	1163.70 (446.48)	.04*
Comprehension time	25956.10 (9051.40)	29187.59 (11331.79)	.23
Lexical decision time	1175.52 (303.09)	1189.87 (361.01)	.89
Semantic decision time	4048.83 (1072.18)	3887.22 (1160.03)	.61
Memory compensation questionnaire			
External aids	3.21 (.45)	3.09 (.58)	.35
Internal mnemonics	2.01 (.55)	2.06 (.62)	.80
Time investment	1.80 (.64)	1.70 (.60)	.56
Recruitment of others	1.06 (.75)	1.33 (.84)	.26
Effort investment	2.21 (.72)	2.38 (.71)	.41
Success/Commitment to memory	1.61 (1.00)	1.80 (.85)	.39
Awareness of changes in compensation	2.38 (.39)	2.37 (.47)	.89

* *Note:* $p < .05$.

TABLE 4

Means (Standard Deviations) for word recall for stroke and control groups in Study 2

Measure	Group		<i>p</i>
	Stroke	Control	
Total number words recalled	15.52 (4.92)	14.54 (4.75)	.54
Number of categories recalled	4.44 (.65)	4.42 (.67)	.80
Mean words recalled per category	3.10 (.98)	2.91 (.95)	.54
Number of intrusions	.79 (.94)	1.13 (1.62)	.12
Number of repeated words	.08 (.19)	.13 (.22)	.27
Clustering	.68 (.25)	.71 (.25)	.37