Cognitive support at encoding attenuates age differences in recollective experience among adults of lower frontal lobe function

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Abstract

Free recall and recollective experience were investigated in relation to neuropsychological measures of frontal lobe function (FLF) among 105 healthy adults divided into three age groups; young (M = 21.82 years), young-old (M = 64.69 years), and old-old (M = 70.69 years). Participants were tested on free recall and recognition of word lists in each of two study conditions. In the first, semantically related words were organizable into one of four taxonomic categories, whereas in the second (random) condition, words were semantically unrelated. Results in respect of free recall showed memory performance was inferior with increasing age, lower FLF, and random encoding condition. There were no interactions involving those variables. With regard to recollective experience, a similar pattern of results was obtained. However, analyses also identified a significant interaction, suggesting old-old adults of lower FLF to exhibit poorer recollective experience. This interaction was significantly modified when semantic organization was available at study. Recognition measures classified as familiar did not vary as a function of age, neuropsychological function, or encoding condition. The results are consistent with the view that autonoetic consciousness, supported by the neural systems of the prefrontal cortex, underpins recollective experience. Further, among older adults, cognitive support at encoding attenuates the detrimental effects of individual differences in those neural systems, in relation to recognition performance.

Introduction

It is important to explore the neural mechanisms underpinning episodic memory deficits in old age, and identify moderators of those deficits. Evidence that the frontal lobes undergo some of the most marked neurological changes with increasing age is, therefore, of some interest. Reviews by Lowe and Rabbitt (1997), Phillips, MacPherson and Della Sala (2002), and West (1996) cite evidence of age-related reductions in the frontal cortex of size and number of neurons, density of presynaptic terminals, volume, and blood flow, relative to other brain areas. Such age-related physiological changes, combined with age differentials in the performance of behavioral tasks thought to rely on frontal systems, has led neuroscientists to propose frontal lobe theoretical accounts of cognitive decline in old age, both general (e.g., West, 1996), and specific to memory (e.g., Moscovitch & Winocur, 1995; Parkin, 1997). This work is of particular interest, as there is evidence that the frontal cortex is involved in both encoding and retrieval stages of episodic memory (e.g., Nolde, Johnson, & Raye, 1998; Wheeler, Stuss, & Tulving, 1997).

Frontal lobe theoretical accounts of cognitive aging propose the detrimental influence of lower frontal lobe function (FLF) on cognitive performance grow greater with increasing age. However, the degree of age-related deficits are unlikely to be uniform between individuals. The present research investigates this issue by examining age differences in free recall and recollective experience in relation to FLF, and the degree of cognitive support at encoding. Specifically, the research asks, do age differences in free recall and recognition vary as a function of FLF, and is this relationship moderated by cognitive support at encoding?

Conscious awareness and episodic memory

The accumulating empirical evidence of the role of the frontal cortex in episodic memory has prompted Wheeler et al. (1997), following Tulving (1985), to distinguish between autonoetic and noetic forms of consciousness. They suggest a key role of the frontal cortex is to confer self-awareness on episodic memory (i.e., autonoetic consciousness), enabling mental timetravel such that we can intimately recreate and relive subjective experiences in our past. This contrasts with semantic memory which involves noetic consciousness, and is concerned more with the storage of knowledge and facts. Wheeler et al. (1997) speculate that the most anterior regions of the frontal cortex are likely to be responsible for autonoetic consciousness. Work by Henson, Rugg, Shallice, Josephs and Dolan (1999) is consistent with this view in that right dorsolateral activation was interpreted as being related to the monitoring associated with the sociotemporal context of a word's previous occurrence (a process necessary for recollective experience). Moreover, it has been suggested that operations performed in the prefrontal cortex during encoding such as semantic elaboration and organization (both conscious processes), provide inputs to the medial temporal memory system (Brewer, Zhao, Desmond, Glover, & Gabrieli, 1998; Wagner, Schacter, Rotte, et al., 1998), an area displaying elevated activation during recollective experience (Eldridge, Knowlton, Furmanski, Bookheimer, & Engel, 2000). Such findings are consistent with Moscovitch and Winocur's (1995) "working-with-memory" hypothesis, where strategic processes governed by the frontal cortex interact with the hippocampal-associative memory system. Together the above suggests the prefrontal cortex to confer conscious awareness on episodic memory functions.

Remembering and Knowing

Tulving's (1985) distinction between autonoetic and noetic consciousness in episodic memory has provided focus for the work of Gardiner and associates (e.g., Gardiner, 1988; Gardiner & Java, 1993), who separate "remembering" and "knowing" responses in recognition experiments. According to Gardiner and Richardson-Klavehn (2000) remembering involves autonoetic consciousness, and "…refers to intensely personal experiences of the past – those in which we seem to recreate previous events and experiences with the awareness of reliving these events and experiences mentally." (p. 229). Knowing relies on noetic consciousness, and involves "…other experiences of the past, those in which we are aware of knowledge that we possess but in a more impersonal way. There is no awareness of reliving any particular events and experiences." (p. 229). Within the formulation of Tulving (1985), and Wheeler et al. (1997), remembering possesses the characteristics of the episodic memory system, while knowing relates more to the semantic memory system. Given the forementioned theoretical and empirical work suggesting the role of the prefrontal cortex in autonoetic consciousness, one would expect behavioral measures of FLF to correlate with remember responses, but not know responses, particularly within the context of aging. What evidence is there to support this?

Several studies have investigated remembering and knowing in relation to age (e.g., Java, 1996; Mantyla, 1993; Parkin & Walter, 1992; Perfect & Dasgupta, 1997; Perfect, Williams, & Anderton-Brown, 1995). The predominant finding is that while remembering decreases with age, knowing is either age invariant, or under certain circumstances, increases with age. For example Perfect et al.'s (1995) data suggest the depth of encoding to be influential: if older adults are required to elaborate at encoding (e.g., through imagery or semantic association), know responses remain the same. In the absence of such instructions, know responses increase with age at subsequent retrieval; in such circumstances older adults report higher levels of recognition without recollective experience.

Turning to studies examining FLF, age, and recollective experience, the evidence is mixed. Parkin and Walter (1992) found the extent to which older adults reported remember responses, correlated with measures of FLF. However, the forementioned study by Perfect et al. (1995) found no such association, and that of Perfect and Dasgupta (1995) found only weak evidence of the involvement of the frontal lobes. Perfect and Dasgupta note this inconsistency may be due to the range and number of frontal lobe measures recorded (although there was direct overlap with Parkin & Walter). Another possibility is that the strength of association between FLF measures and age differences in episodic memory varies as a function of the cognitive demands of the task. Such demands can be moderated by the level of cognitive support at encoding or retrieval.

Cognitive support and episodic memory

The idea that the external context may induce or support the mental operations required at the encoding and retrieval stages of episodic memory, particularly in respect to older adults, has received considerable attention (see Craik & Jacoby, 1996). Generally, various forms of such support have been found to moderate age differences in episodic memory (e.g., Bäckman, Mäntylä, & Herlitz, 1990). Given evidence that cognitive support in the form of item organizability at encoding benefits the memory performance of older adults (Bäckman & Wahlin, 1995), what indications are there, that the utilization of such support is related to the prefrontal cortex?

A body of research suggests patients with frontal lobe damage have difficulty spontaneously categorising word lists, or using other top-down organizational strategies, and that when induced to organize lists, recall generally improves (Eslinger & Grattan, 1994; Hirst & Volpe, 1988; Gershberg & Shimamura, 1995; Stuss, Alexander, Palumbo, Buckle, Sayer, & Pogue, 1994). For instance, Gershberg and Shimamura (1995) produced evidence of organizational strategies benefiting both encoding and retrieval phases of free recall, and speculated that lesions of the dorsolateral prefrontal cortex particularly affect the ability to use organizational strategies. Positron emission tomography studies suggest both deeper and more effective encoding of to-be-remembered materials are associated with activation of the left prefrontal cortex (Nyberg, Cabeza, & Tulving, 1996; Wheeler it al, 1997). Together, this research implies a relationship between the prefrontal cortex, and utilization of item organizability during encoding of episodic memory materials. However, no research has examined that relationship among healthy adults of different ages, in whom individual differences in FLF are likely to exist.

The present research therefore, adds to earlier work by investigating if provision of cognitive support through the opportunity to classify word lists into taxonomic categories at study (versus random word lists), moderates age differences in free recall and recollective experience. Associations with behavioral measures of FLF will be examined to assess the extent to which such cognitive support at encoding moderates episodic memory performance in older adults of lower FLF.

Method

Participants

A total of 105, healthy adults (47 men) participated in the study, divided into three age groups, young, young-old (YO), and old-old (OO). Younger adults were students of the University of London, and older participants were recruited through advertising and contacts at local church groups and charity organizations. The younger group (n = 50) ranged from 18 to 32 years, and had a mean age of 21.82 years. The YO group (n = 26) were aged between 59 and 67 years (M = 64.69), and the OO group (n = 29) were aged 68 to 78 years (M = 70.69). The older participants predominantly came from professional backgrounds, and the three age groups were matched according to the National Adult Reading Test Full Scale IQ (NART: Nelson, 1982). Adults over 65 were screened for signs of dementia using the Mini-Mental State Examination (MMSE: Folstein, Folstein, & McHugh, 1975). All those taking part in the present study scored 25 or more on that measure.

Materials

Episodic memory task. Two lists of 12 concrete nouns were prepared. In the first list, words fell into four semantically related categories (animals, musical instruments, items of furniture, rooms in a house), each consisting of three one-syllable words. This list was used in the organizability encoding (i.e., cognitive support) condition. The second list forming the random encoding condition, consisted of 12 semantically unrelated concrete nouns. Participants performed both conditions during the experimental session. At study, words were presented individually, and bi-modally (spoken by the experimenter, and presented on cards simultaneously) for 2 s each. Immediately following presentation, participants were asked to free recall as many words as possible from the list. Two minutes were allowed for this purpose.

A recognition test was then administered. The 12 words from the two respective lists were intermixed with 12 semantically unrelated “lure” concrete nouns. Participants were required to circle items they recognized, and in doing so, classify them as either “remember” or “know”. Following Gardiner (1988), ‘“remember” was defined …as the ability to become consciously aware again of some aspect or aspects of what happened or what was experienced at the time the word was presented (e.g., aspects of the physical appearance of the word, or of something that happened in the room, or of what one was thinking or doing at the time). “Know” responses were defined as the recognition that the word was…[presented]…but the inability to recollect consciously anything about its actual occurrence or what happened or what was experienced at the time of the occurrence” (p. 311: inset amended to the present context). The illustrations described by Gardiner were used to clarify the distinction. For the 48 words used in the experiment, mean scores in terms of frequency, concreteness, and imageability were 148.80, 575.06, and 575.79 respectively.

Frontal tasks. The following four measures were administered according to standard protocols unless otherwise stated; FAS Word Fluency Test (Benton, Hamsher, Varney & Spreen, 1983), the Alternate Uses Test (Guildford, Christensen, Merrifield, & Wilson, 1978), and the Food Test (Isaacs & Kenny, 1973) the latter administered according to the procedures used by Parkin, Walter, & Hunkin (1995). The final measure was the alternate generation of animal and country names test used by Parkin et al. (1995). Here, participants were required to generate alternately animals and countries without repetition or deviation.

Procedure

Participants attended the laboratory by appointment. On arrival they completed an informed consent form, and then those aged 65 and over were screened using the MMSE. At this point several physiological measures were recorded relating to another aspect of the study (two of these measures, blood pressure, and arterial oxygen content, were administered at several points across the test session). A self-completion biographical questionnaire was administered, followed by NART. Participants then performed the first of the two episodic memory conditions (random or organizable words) which were balanced across the test session. A battery of cognitive tests which included the frontal measures were then administered. To finish, participants completed the second episodic memory condition. They were then debriefed, and those who were non-students received a payment of £6.50 Sterling.

Psychology students taking part received course credits required for completing their degree. The entire session lasted approximately one hour.

Results

Initially, the four frontal lobe function (FLF) measures were subjected to principal component analyses. As expected, the measures loaded onto a single factor, accounting for 50.92 percent of the variance. Therefore, it was decided to determine high and low frontal function, within each age group, through median splits on the factor scores for that group. Before the main statistical analyses were run however, recognition scores were inspected for evidence of ceiling effects. For the young, young-old (YO), and old-old (OO) groups, respectively, six, one, and two, participants were found to have recorded the maximum possible number of remember responses in either condition, or both. As such high scoring may introduce artefactual ceiling effects, it was decided to remove those participants from the main statistical analyses. To confirm that removal of those individuals did not affect the initial factor structure, frontal lobe measures were once again subjected to principal component analysis. Again, one factor was extracted accounting for 51.25 percent of the variance (factor loadings: FAS = .806; Food Test = .699; Alternating Fluency = .676; Alternate Uses = .675). Median splits on the factor scores then determined individuals of high and low FLF within each age group. As findings did not differ substantially from those involving the original sample, for parsimony, analyses also were conducted on free recall scores in the reduced sample of 96 individuals.

Table 1 about here

Descriptive means according to age and FLF group are shown in Table 1. To ensure that within each age group chronological age did not vary significantly as a function of frontal lobe group, that variable was subjected to a 3 (age group) x 2 (FLF) analyses of variance (ANOVA). The absence of a significant Age Group x FLF interaction ($p>.25$) suggested chronological age was matched regardless of frontal lobe group. A second ANOVA showed higher FLF groups possessed significantly higher NART scores ($p<.001$), while a $\underline{X}^2$ test showed gender not to differ significantly among groups. As NART varied significantly according to FLF group, and small cell sizes meant gender could not be treated meaningfully as a between-subjects factor, both variables were entered as covariates in all of the Analyses of Covariance (ANCOVA) reported below.

ANOVAs were repeated with each of the individual neuropsychological measures as dependent variables. In each case the main effect for FLF group was significant (all $p < .001$), and the interaction with age was nonsignificant (all $p > .15$). This indicated each of the neuropsychological measures recorded significantly greater scores in the higher FLF groups, regardless of age group. This can be seen in Table 1.

In respect to free recall and recognition measures, a series of 3 (age group) x 2 (FLF group) x 2 (encoding condition) x 2 (order in which encoding condition was administered) univariate ANCOVAs were run (NART and gender were entered as covariates). As no significant main effect or interactions were identified in respect to the order in which encoding conditions were administered, data for that factor were collapsed for the purposes of reporting below.

Free recall

Free recall scores according to age, FLF, and encoding condition, are presented in Table 2. ANCOVA identified main effects for age, $F(2,88) = 13.08$, $\eta^2 = .229$, $p = .001$; FLF, $F(1,88) = 8.20$, $\eta^2 = .085$, $p = .005$; and encoding condition, $F(1,90) = 33.86$, $\eta^2 = .273$, $p = .001$. In respect to age, younger adults produced superior recall (.715) than both YO (.580) and OO (.593) adults. Higher FLF groups recalled more (.672) than lower FLF groups (.586), and the organizable encoding condition was associated with a higher recall (.688) than the random encoding condition (.597). However, all interactions involving those variables were found to be nonsignificant (all $p > .4$). Therefore, neuropsychological function and cognitive support at encoding, did not appear to moderate age differences in free recall.

Recollective experience

As there is a possibility that response bias may operate systematically according to age, neuropsychological function, or interactions between those variables, it was desirable to subject remember-words to statistical analysis using metrics arising from signal detection theory. Possible bias would not be taken into account in separate analyses of hit and false alarm rates. For those reasons, the theoretically bias free measure A' (Pollack & Norman, 1964) was employed. This metric has a range of 0 to 1, with higher values reflecting greater recollective experience. Hits and false alarms for remember-words were also subjected to analyses, as was the criterion measure B''_D (Donaldson, 1992). As the measurement status of know-words is less clear (e.g., Jacoby, Yonelinas, & Jennings, 1997; Gardiner, Ramponi, &

Richardson-Klavehn, 1998), only hits and false alarms were examined for this type of response. Recognition data according to age, FLF and encoding condition is displayed in Table 2.

Table 2 about here

Remember responses (A'). While the main effect for age attained statistical significance, $F(2,88) = 4.95$, $\eta^2 = .101$, $p = .009$, that for FLF did not ($p > .075$). A' scores indicated the ability to distinguish target from lure words decreased with greater age (young = .844, YO = .784, OO = .760). That main effect was modified by a significant Age x FLF interaction, $F(2,88) = 3.26$, $\eta^2 = .069$, p = 043. Simple effects found A' scores not to significantly vary as a function of FLF within young participants (low = .867, high = .821: $p > .34$), or YO adults (low = .761, high = .807: $p > .16$). However, that test was significant for OO adults (low = .724, high = .796: $p = .035$). Thus, as age increases, recognition for remember words decreases to a greater degree in adults of lower FLF.

The main effect for encoding condition was also significant, $F(1,90) = 5.99$, $\eta^2 = .062$, $p = .016$. A' scores where higher in the organizable (.818) than the random (.790) encoding condition. The two-way interactions involving age and encoding condition, and FLF and condition, were both nonsignificant (both $p > .15$).

Finally, the three-way interaction involving age, FLF, and encoding condition attained significance, $F(2,90) = 3.31$, $\eta^2 = .069$, $p = .041$. Subsequent simple tests showed the lower level interaction between age and encoding condition to be nonsignificant among those of higher FLF ($p > .78$). However, that interaction within the lower FLF group was significant ($p = .006$). Simple simple tests for differences in A' scores within each of the age groups at the lower level of FLF, found encoding condition not to vary significantly within the younger ($p > .99$), and YO ($p > .76$) age groups. However, among OO adults, A' scores suggested discriminability was significantly greater in the organizable encoding condition ($p < .001$). Thus, the source of the three-way interaction stemmed from older adults of lower FLF producing fewer remember-words in the random encoding condition (see Table 2).

Remember responses (proportional raw scores). Statistical analysis of proportional raw scores for correct recollection revealed a significant main effect for age, $F(2,88) = 3.48$, $\eta^2 = .073$, $p = .035$, and a significant interaction between age and FLF, $F(2,88) = 3.46$, $\eta^2 = .073$, $p = .036$. Simple tests examined performance within each age group as a function of

FLF. Those tests were not significant in the young (low = .526, high = .446, $p>.34$), or YO groups (low = .339, high = .445, $p>.13$). However, the equivalent test in the OO group did attain statistical significance (low = .292, high = .440, $p = .026$). Thus, the magnitude of the performance deficit as a function of FLF, was greater among the oldest participants, relative to those in the two younger age groups. The main effect for FLF was not significant ($p>.065$), while that for encoding condition did attain statistical significance, $F(1,90) = 7.18$, $\eta^2 = .074$, $p = .009$; performance in the organizational condition ($M = .458$) was superior to that in the random condition ($M = .391$). All other interactions were statistically unreliable ($p>.25$).

In relation to the proportion of false alarms, all statistics were nonsignificant (all $p>.22$), except for the threeway interaction involving age, FLF, and encoding condition, $F(2,90) = 3.83$, $\eta^2 = .078$, $p = .025$. That interaction was due to OO adults of lower FLF producing a relatively higher proportion of false alarms in the random encoding condition (see Table 2). Simple tests found the Age x Condition interaction to be significant among individuals of lower ($p = .047$), but not higher, FLF ($p > .40$). Within the lower FLF group, simple simple tests found encoding condition to be nonsignificant in the young and YO groups (both $p>.57$), in contrast to the OO group, where that test did attain significance ($p = .012$).

Remember responses criterion (B''_D). To what extent were the above findings related to criterion shifts? The ANCOVAs were repeated, but using the criterion measure B''_D as the dependent variable. All statistics were nonsignificant ($p>.20$). This would strongly suggest that response bias was not responsible for the foregoing findings.

Know responses (proportional raw scores). A further ANCOVA undertaken in respect to hits for know-words did not produce any significant statistics (all $p>.12$). For false alarms, the only statistic achieving statistical significance was that for encoding condition, $F(1,90) = 11.00$, $\eta^2 = .109$, $p = .001$; more erroneous know-responses were produced in the random condition ($M = .045$) relative to the organizational condition ($M = .024$). All other statistics were nonsignificant (all $p>.05$).

In sum, these results indicate that providing cognitive support at the encoding phase of this experiment moderated age differences in recollective experience for adults aged over 67 of lower FLF. Moreover, this moderating effect was found in relation to remember-words, hypothesised as tapping the episodic memory system and reliant on the prefrontal cortex, but not know-words supported by the semantic memory system. The findings in respect to recollective experience were statistically significant for A' and false alarm scores. Hit rates, although not significantly, exhibited a similar data trend (see Table 2). Results in relation to B''_D, suggested response bias was not responsible for those findings.

Table 3 about here

Although the results so far are supportive of expectations, some questions remain as to their interpretation. Specifically, it was suggested in the introduction that the neuropsychological measures were supported by the neural systems of the prefrontal cortex, and that in recollective experience, these would be sensitive to autonoetic consciousness, tapped empirically by remember responses. The data presented in relation to remembering support this suggestion, as did the nonsignificant associations between FLF measures and know responses, reliant on the semantic memory system. However, it is possible that the findings, and their subsequent interpretation, are an artefact of the between-subjects methodology. There remains a possibility that the composite FLF measure, and indeed the underlying component measures, may tap a more general ability, namely fluid intelligence. If so, fluid intelligence would be expected to correlate with both overall recognition (remember + know responses), and remember responses alone. The between-subjects design may not have been sufficiently sensitive to detect this. In addition, if the influence of the FLF measures on recollective experience is independent of the semantic memory system, associations would remain having statistically controlled for overall recognition. Therefore, a series of regressions were run to explore the possibility that FLF measures may be tapping a more general factor.

In Table 3, three regression models are presented. Overall recognition, and remember words are regressed on FLF measures in the first and second models respectively. It can be seen that within the young, and YO age groups, none of those simple regression equations attained statistical significance. That is also the case among OO adults in the organizational condition. In the random condition, the significant equation in Model 2 where in OO adults, FLF accounts for 15 percent of the variance in recollective experience, accords with the findings described earlier; FLF was most strongly associated with remembering in conditions of high cognitive demands and low support at study. In Model 1 however, FLF significantly predicts overall recognition, explaining 21 percent of the variance. This suggests variation in this older group was associated with both episodic and semantic memory systems in more demanding encoding conditions.

This was explored further in Model 3 where, using a hierarchical procedure, recollective experience was regressed on overall recognition in Step 1, and FLF in Step 2. In both encoding conditions within the younger groups, and in the organizational condition of the OO group, overall recognition significantly predicted recognition of remember-words. However, an important consideration regarding the OO group, is whether the significant association between FLF and remembering semantically unrelated words (Model 2) remains having controlled for overall recognition. Step 2 of the relevant equation in Model 3 shows this association to become statistically unreliable. This would strongly suggest that the influence of FLF on remembering is related to overall recognition ability. In other words, FLF is associated with both the episodic and semantic memory systems. As this finding has important theoretical implications, it is considered further in the Discussion section.

Table 4 about here

Finally, it was of interest to determine the extent to which age associations with remembering were independent of both overall recognition, and FLF. In Table 4, the simple regression in Model 1 shows age to significantly predict remembering in both encoding conditions. In Models 2 and 3, hierarchical regression was used to partial out the effects of, respectively, FLF and overall recognition. In the random, more cognitively demanding encoding condition, although attenuated, age remains significant having controlled for both variables. However, in the organizational condition, the influence of age becomes statistically unreliable after taking FLF and overall recognition into account.

Discussion

This study has investigated free recall and recollective experience in relation to age and neuropsychological function. The moderating influence of cognitive support at encoding was explored also. In respect to free recall, increasing age, lower FLF scores, and lack of cognitive support at encoding were all associated with lower word recall. There were no significant interactions involving those variables. However, a differential pattern of results was found in relation to remembering and knowing. Recollective experience weakened with increasing age, lower FLF, and random encoding conditions. Age differences were modified by neuropsychological function such that remembering decreased significantly with increasing age and lower FLF. That interaction was qualified further though, when cognitive support at encoding was available. Recollective experience in OO adults of lower FLF was significantly better when organizable words were encoded relative to random words. Statistics relating to knowing were nonsignificant, with the exception of the main effect for encoding condition where more false alarms were produced for semantically unrelated words. The significant interactions found for recollective experience were not related to ceiling effects that restricted the range of know responses possible; participants recording maximum scores in respect to remember responses were removed from the statistical analyses. This suggests that the results were due to underlying neural systems subserving the neuropsychological measures.

The findings are supportive of frontal lobe explanations of cognitive aging, and age deficits in memory (Moscovitch & Winocur, 1995; Parkin, 1997; West, 1996), and consistent with empirical work elsewhere (Parkin & Walter, 1992) suggesting age differentials in remembering are moderated in older adults of higher FLF. The reason for the contrast with the null findings of Perfect et al. (1995), and Perfect and Dasgupta (1997) is less clear, although that latter study provided some evidence of the role of the frontal cortex in age differences in recollective experience. One possibility is that using weighted factor scores, which take into account the relative contributions of the individual FLF measures, was a more sensitive approach to the issue. Another possibility is that the larger sample size in the present study afforded a greater level of statistical power.

Results showed FLF did not moderate age differences in free recall, and taking encoding condition into account did not alter this. A possible explanation for the weak relationship derives from Leng and Parkin (1989). They found the association between frontal function and performance of the Brown – Peterson task grew stronger as the retention interval between word presentation and word recall became longer. In the present experiment free recall was required immediately following presentation of the to-be-remembered words. Thus, insufficient time may have elapsed for frontal function to become influential. The greater passage of time before recognition was tested may explain the contrasting findings in respect to the two memory measures.

The association between age, FLF, and recollective experience is supportive of positions (e.g., Wheeler et al.,1997) suggesting neural mechanisms seated in the prefrontal cortex support autonoetic consciousness and underpin episodic memory. The provision of organizable categories at the encoding stage of the experiment, appears to have enhanced the autonoetic awareness of information being processed. The findings suggest semantic associations embedded in the categories (e.g., musical instruments, animals) to have helped participants, particularly those older adults of lower FLF, to recreate events at encoding with a greater awareness, manifest in more effective recognition in the form of remember responses.

It is worth considering further though, what exactly the neuropsychological measures represent. The regression analyses presented in Table 3 suggested the influence of FLF measures on recollective experience to increase with age in circumstances of high cognitive demands (the random encoding condition). However, this was also the case in respect to overall recognition, and further, the influence of FLF on remembering was found to be mediated entirely by overall recognition. This raises the possibility that the FLF measures were tapping a more general factor than a mechanism seated in the frontal cortex specifically related to recollective experience. A strong candidate is fluid intelligence. At first sight this is problematic as there is a common view that fluid intelligence draws upon multiple cognitive functions, supported by diffusely distributed neural systems. However, recent neuroimaging work by Duncan and colleagues (2000), suggests that high g tasks, differing in their functional requirements, are all associated with selective activation of the lateral frontal cortex in one, or both, hemispheres. The findings of the regression analyses suggest the FLF measures were indexing fluid intelligence. Although an independent measure of fluid intelligence was not available to test this possibility directly, the implication is that age-related declines in that general factor are associated with age differences in autonoetic consciousness in remembering, and are particularly apparent in circumstances of high cognitive demands. This is consistent with Duncan et al. in that selective frontal activation was found in respect to high, but not low, g tasks. This possibility is worthy of further investigation, both from neuropsychological and cognitive neuroscience perspectives.

The present findings add to investigations showing patients with frontal lesions to benefit from organizational strategies at encoding (e.g., Gershberg & Shimamura, 1995). Moreover, the data suggest, contrary to frontal lobe lesions studies, that healthy aging adults of lower FLF are able to spontaneously utilize organizational strategies at encoding (at least following the present experimental protocol), without being explicitly instructed to do so. This finding is consistent with Bäckman and Wahlin (1995). This may explain the lack of age effects in respect to know-words, thereby supporting the reasoning of Perfect et al. (1995). That is, although no explicit instructions were given to elaborate at study in the present experiment (which leads to the prediction of inflated know-responding in older individuals), unprompted utilization of organizability appears to have produced a similar effect to explicit encoding instructions. However, as age differences were absent in the random condition, it is not possible to draw a firm conclusion here. In addition, there is a suggestion in the present data that involvement of the prefrontal cortex in semantic elaboration and organization (Brewer et al., 1998; Wagner et al., 1998) during encoding, may have raised autonoetic consciousness; the recollective performance of older lower frontal function adults improved significantly in the encoding condition facilitating such processing, but not in the random condition. This finding is also supportive of Perfect and Dasgupta's (1997) position that age differences in recollective experience are due to an encoding rather than retrieval deficit.

Systematic variation in criterion does not appear to have influenced the findings. When statistical analyses were repeated using the criterion measure, none of the critical interactions attaining significance in respect to recollective experience, were significant. This would suggest that the findings in this study were underpinned by the neural substrates of cognitive performance rather than individual differences in response bias.

Given the evidence of prefrontal influence in age differences in recollective experience demonstrated by this study, and others (Parkin & Walter, 1992), it is worthwhile speculating why some, but not all, older adults appear to suffer greater frontal lobe and episodic memory deficits in old age. One possibility is genetic. For example, Hofer, Christensen, Mackinnon et al. (2002) demonstrated that non-demented older adults possessing the apolipoprotein E (apoE) allele $\epsilon 4$, showed greater episodic memory decline than non-$\epsilon 4$ carriers. Given the frontal cortex is implicated in that measure, it is possible that apoE genotype may influence the rate of neural degeneration in this brain region with increasing age. A second possibility is lifestyle. Several studies have suggested that a higher level of aerobic fitness in older adults is associated with superior performance on frontally reliant cognitive measures, than more sedentary age cohorts (Bunce, 2001; Bunce, Barrowclough, & Morris, 1996; Kramer, Hahn, Cohen, et al., 1999). Thus, the benefits of physical exercise to cardiovascular status and aerobic condition, may help attenuate age-related neurological changes in the frontal cortex.

To conclude, this study has produced evidence suggesting the prefrontal cortex to be involved in recollective experience, and that the association grows greater with increasing age. This finding is consistent with the view that one of the factors underpinning cognitive aging in healthy adults is frontal neural degeneration. The research also suggests the neural structures of the frontal cortex are central to the autonoetic awareness distinguishing episodic from semantic memory. Moreover, the possibility that in cognitively demanding situations, age-related declines in general fluid intelligence are involved, should be subjected to future investigation.

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Table 1. Means (SDs) for Chronological Age, NART, and Neuropsychological Measures According to Age and Frontal Lobe Function Group

	Young		Young-Old		Old-Old	
	Low	High	Low	High	Low	High
No. Subjects	23	21	13	12	15	12
No. Women	17	8	9	9	7	4
Chron. Age	21.00 (3.19)	22.43 (3.75)	64.46 (2.88)	65.08 (1.73)	71.20 (3.08)	70.25 (1.06)
NART	110.09(7.05)	115.86(5.40)	105.85(10.44)	120.67(6.30)	100.40(20.53)	117.58(10.24)
FAS	36.39 (7.76)	50.29 (8.39)	30.46 (7.70)	48.75(11.71)	33.60(12.62)	54.33 (9.29)
Food	22.87 (4.45)	29.29 (3.72)	22.77 (4.68)	25.17 (3.79)	21.47 (3.76)	26.33 (5.07)
Alt. Uses	19.65 (5.99)	25.24 (6.32)	13.62(2.66)	18.67(10.00)	15.73 (5.69)	22.58 (6.61)
Alt. Fluency	19.44 (4.67)	23.62 (5.20)	16.08 (4.50)	23.50 (3.21)	17.87 (4.17)	22.83 (3.76)

Note. NART = National Adult Reading Test

Table 2. Means (SDs) of Free Recall and Recognition Scores as a Function of Age and Frontal Lobe Function Group

	Young		Young-Old		Old-Old	
	Low	High	Low	High	Low	High
Free Recall						
Org.	.721 (.117)	.784 (.165)	.571 (.131)	.681 (.122)	.594 (.160)	.708 (.151)
Random	.670 (.127)	.683 (.159)	.462 (.143)	.604 (.171)	.500 (.118)	.569 (.154)
R-Words						
A’	.867 (.090)	.840 (.131)	.756 (.183)	.816 (.162)	.777 (.155)	.803 (.157)
Org.						
Random	.867 (.039)	.801 (.136)	.765 (.158)	.799 (.142)	.671 (.152)	.788 (.179)
Hits						
Org.	.548 (.207)	.489 (.287)	.356 (.287)	.473 (.305)	.363 (.284)	.446 (.326)
Random	.504 (.134)	.402 (.251)	.323 (.242)	.398 (.219)	.220 (.182)	.433 (.306)
FAs						
Org.	.020 (.050)	.010 (.000)	.010 (.000)	.023 (.045)	.020 (.040)	.029 (.048)
Random	. 013(.015)	.020 (.026)	.010 (.000)	.016 (.021)	.052 (.078)	.016 (.021)
K-Words						
Hits						
Org.	.327 (.225)	.381 (.236)	.437(.249)	.417(.309)	.461 (.281)	.424 (.266)
Random	.334 (.139)	.429 (.245)	.393 (.262)	.409 (.260)	.460 (.271)	.356 (.310)
FAs						
Org.	.027 (.053)	.013 (.016)	.027 (.032)	.029 (.048)	.035 (.047)	.016 (.021)
Random	.030 (.048)	.028 (.041)	.065 (.106)	.055 (.093)	.082 (.076)	.022 (.029)

Notes. Org. = Organizable
Hits = Proportion hits
FAs = Proportion false alarms

Table 3. Simple and Hierarchical Regression Analyses involving Remembering, Overall Recognition, and Frontal Lobe Function

		Model 1			Model 2			Model 3		
		Step	Beta	ΔR^2	Step	Beta	ΔR^2	Step	Beta	ΔR^2
Young										
	Random	DV=Recog			DV = Rem			DV = Rem		
		1 FLF[a]	-.03	.00	1 FLF[a]	-.21	.05	1 Recog[d]	.33	.12*
		2 -			2 -			2 FLF[e]	-.20	.04
	Organizational	DV=Recog			DV = Rem			DV = Rem		
		1 FLF[a]	-.13	.02	1 FLF[a]	-.11	.01	1 Recog[d]	.37	.16***
		2 -			2 -			2 FLF[e]	-.07	.00
Young Old										
	Random	DV=Recog			DV = Rem			DV = Rem		
		1 FLF[b]	.31	.09	1 FLF[b]	.03	.00	1 Recog[f]	.37	.12
		2 -			2 -			2 FLF[g]	-.08	.00
	Organizational	DV=Recog			DV = Rem			DV = Rem		
		1 FLF[b]	.33	.11	1 FLF[b]	.21	.04	1 Recog[f]	.37	.16
		2 -			2			2 FLF[g]	.09	.00
Old Old								3 -		
	Random	DV=Recog			DV = Rem			DV = Rem		
		1 FLF[c]	.45	.21**	1 FLF[c]	.38	.15*	1 Recog[h]	-.05	.02
		2 -			2 -			2 FLF[i]	.41	.13
	Organizational	DV=Recog			DV = Rem			DV = Rem		
		1 FLF[c]	.14	.02	1 FLF[c]	.19	.04	1 Recog[h]	.42	.19*
		2 -			2 -			2 FLF[i]	.13	.02

Notes

d.f. a=1,42; b=1,23; c=1,25; d=1,42; e=1,41; f=1,23; g=1,22; 1,25; i=1,24

*p<.05; **p<.02; ***p<.01

Rem = Remember words; Recog= Overall Recognition; FLF = frontal lobe function

Table 4. Simple and Hierarchical Regression Analyses involving Remembering, Overall Recognition, Frontal Lobe Function, and Age

	Model 1			Model 2			Model 3		
	Step	Beta	Δ R^2	Step	Beta	Δ R^2	Step	Beta	Δ R^2
Random[1]	DV = Rem			DV = Rem			DV = Rem		
	1 Age[a]	-.29	.08***	1 FLF[a]	.05	.02	1 Recog[a]	.27	.11***
	2 -			2 Age[b]	-.27	.07***	2 Age[b]	-.21	.04*
Organizational	DV = Rem			DV = Rem			DV = Rem		
	1 Age[a]	-.20	.04**	1 FLF[a]	.08	.02	1 Recog[a]	.16	.04*
	2 -			2 Age[b]	-.18	.03	2 Age[b]	-.16	.02

Notes.

d.f. a=1,94; b=1,93

*p<.05; **p<.02; ***p<.01

Rem = Remember words; Recog= Overall Recognition; FLF = frontal lobe function