Neuropsychology
1994, Vol. 8, No. 3, 408–412

0894-4105/94/$3.00

Memory Interference Effects and Aging: Findings From a Test of Frontal Lobe Function

Arthur P. Shimamura and Paul J. Jurica

Performance on behavioral measures of self-ordered pointing and 2-choice recognition memory was evaluated in young adults (aged 18–23 years) and 2 groups of older adults (aged 61–70 years and 71–80 years). The self-ordered pointing test involves working memory and has been used as an index of frontal lobe dysfunction; to perform well, subjects must organize stimulus information and monitor responses. Both groups of older adults exhibited impairment on the pointing test, but the pattern of impairment was different for the 2 groups. Individuals in their 60s exhibited impairment on a second block of trials but not on the first block. Individuals in their 70s exhibited deficits on both blocks of trials. On the recognition test, only individuals in their 70s exhibited impairment. The findings suggest that age-related impairments occur in both working memory and recognition memory.

Studies of age-related changes in cognitive function have benefited from neuropsychological analyses of brain-injured patients (see Albert & Moss, 1988; Butters, 1980; Moscovitch & Winocur, 1992; Shimamura, 1990). For example, neuropsychological measures can be helpful in aging research because one can select tests that are sensitive to dysfunction in specific brain regions. Theoretically, it may be possible to determine if some functions (e.g., new learning or word finding) are disproportionately affected by aging. Finally, an understanding of age-related neurological disorders, such as Alzheimer's disease and Parkinson's disease, may be benefited by investigations of the neuropsychological profile associated with normal aging.

The focus of the present investigation is the application of neuropsychological tools to the study of age-related cognitive decline on tests sensitive to frontal lobe or medial temporal lobe dysfunction. Tests sensitive to medial temporal lobe lesions have been used extensively in studies of cognitive aging (for reviews, see Albert & Moss, 1988; Butters, 1980; Craik, 1977; Kausler, 1991; Light & Burke, 1988; Salthouse, 1991). These studies suggest that some aspects of age-related memory impairment are similar to those observed in amnesic patients with medial temporal lesions. It is important to note, however, that age-related deficits are much less severe than those observed in amnesic patients. Specifically, older adults exhibit subtle but significant declines on various measures of new learning capacity such as free recall, paired-associate learning, and recognition memory (Albert & Moss, 1988; Craik, 1977; Kausler, 1991).

Less is known about the aging pattern associated with frontal lobe function. Tests of frontal lobe function involve selective attention to specific stimuli, planning of strategies, monitoring of responses, and other metacognitive abilities (see Milner, Petrides, & Smith, 1985; Shimamura, Janowsky, & Squire, 1991; Stuss & Benson, 1986). In the domain of memory function, both free recall and memory for temporal order (e.g., recency and source monitoring) are particularly affected by frontal lobe lesions (Janowsky, Shimamura, & Squire, 1989; Milner et al., 1985; Shimamura, Janowsky, & Squire, 1990). Prominent among these deficits is a problem in the ability to monitor irrelevant, interfering, or inappropriate information. Indeed, some have conceptualized the deficit observed on tasks sensitive to frontal lobe dysfunction as an impairment in executive control or working memory (Baddeley, 1986; Goldman-Rakic, 1987; Shimamura, in press).

Age-related deficits on tests of frontal lobe function have been demonstrated on some neuropsychological measures (for reviews, see Albert & Kaplan, 1980; Moscovitch & Winocur, 1992; Shimamura, 1990). For example, age-related changes have been observed on the Wisconsin Card Sorting Test (WCST), the Stroop Color–Word Interference Test, and verbal fluency tests (Comalli, Wapner, & Werner, 1962; Obler & Albert, 1985; Whelihan & Lesher, 1985). In addition, age-related memory deficits occur prominently on tests of memory for temporal order, such as tests of recency and source memory (Janowsky et al., 1989; McIntyre & Craik, 1987; Naveh-Benjamin, 1990). Indeed, McIntyre and Craik (1987) showed that memory for source information was correlated with performance on the WCST in older adults. These findings suggest some parallels between age-related deficits and deficits associated with frontal lobe lesions. It should be noted, however, that frontal lobe dysfunction, alone, cannot account for the entire spectrum of cognitive changes associated with aging. For example, deficits in memory formation or visuospatial processes may be

Arthur P. Shimamura and Paul J. Jurica, Department of Psychology, University of California, Berkeley.

This research was supported by Grant AG09055 from the National Institute on Aging. We thank Stephanie Erber, Katherine Stone, and the staff at the Institute of Personality and Social Research, University of California, Berkeley, for research assistance.

Correspondence concerning this article should be addressed to Arthur P. Shimamura, Department of Psychology, University of California, Berkeley, California 94720. Electronic mail may be sent via Internet to aps@garnet.berkeley.edu.

the result of disruption to other cortical functions (see Janowsky & Thomas-Thrapp, 1993; Shimamura, 1990).

In the present study, we assessed age-related changes on a measure that has been effective in neuropsychological analyses of frontal lobe dysfunction. We administered the self-ordered pointing test, a test that appears to involve working memory and the ability to monitor responses to stimuli (Petrides & Milner, 1982). In our version of the test, subjects were presented with an array of 16 visual patterns (see Figure 1). On each of 16 presentations of the array, subjects were instructed to point to one of the patterns with the restriction that they should try to point to a different one on each trial. We increased the demand on working memory by having subjects perform the task again using the same stimulus array. In this way, we required subjects to monitor responses both within and between blocks of trials. We also administered a two-alternative, forced-choice recognition memory test. To evaluate age declines more closely, we tested two groups of elderly individuals, a group of subjects aged 61–70 years and an older group of subjects aged 71–80 years. We divided the elderly individuals into these two subgroups because recent longitudinal findings have shown that large age effects in cognitive decline can be observed between subjects in their sixties and subjects in their seventies (see Schaie, 1990).

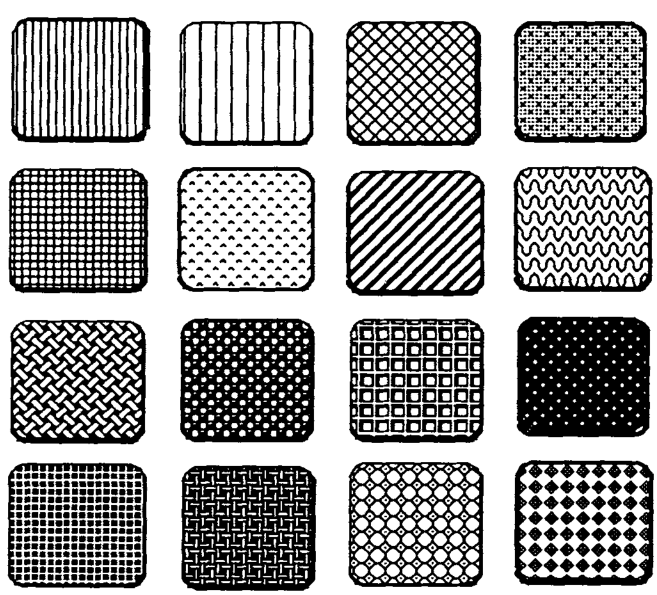

Figure 1. Stimulus array presented in the self-ordered pointing task. On each of 16 trials, the positions of the stimuli were randomly varied, and subjects were instructed to point to 1 of the 16 stimuli with the restriction that they should point to a different stimulus on each trial. Two blocks of trials were presented with the same set of stimuli.

Method

Subjects

Three age groups were assessed. One group consisted of college undergraduate students with a mean age of 19.8 years (n = 41; range = 18–23 years); another group consisted of healthy elderly individuals with a mean age of 66.5 years (n = 17; range = 61–70 years); and the third group consisted of healthy elderly individuals with a mean age of 75.4 years (n = 11; range = 71–80 years).

The young volunteers averaged 14.4 years of education and scored 55.6 on the Vocabulary and 69.7 on the Digit Symbol subtests of the Wechsler Adult Intelligence Scale—Revised (WAIS–R). Their average self-report ratings of physical health and mental health (1 = *poor,* 7 = *excellent*) were 5.37 and 5.51, respectively. These individuals received course credit or were paid for participation in the experiment.

The older subjects were all community-dwelling individuals who were paid for participation in the experiment. The subjects in their sixties averaged 16.8 years of education and scored 61.4 on the Vocabulary and 48.8 on the Digit Symbol subtests of the WAIS–R. Their average self-report ratings of physical health and mental health were 5.12 and 5.23, respectively. The subjects in their seventies averaged 16.3 years of education and scored 59.5 on the Vocabulary and 46.5 on the Digit Symbol subtests of the WAIS–R. Their average self-report ratings of physical health and mental health were 5.36 and 6.0, respectively. Thus, the elderly subjects conformed to standard elderly samples by demonstrating preserved performance on the Vocabulary subtest of the WAIS–R but impaired performance on the Digit Symbol subtest.

Procedure

In the self-ordered pointing task, subjects viewed an array of 16 visual patterns (see Figure 1) and were instructed to use a mouse input device to point to a pattern in the array. On each of the next 15 trials, subjects were asked to point to a pattern with the restriction that they should never point to one that had been selected on a previous trial. The location of a pattern was randomly determined for each trial, and performance was self-paced, with a subject's response initiating the beginning of the next trial. Upon completion of a block of trials, subjects repeated the task in a second block of 16 trials involving the same patterns. Practice trials with a simplified 3 × 3 stimulus array were administered to ensure that subjects understood the instructions. A Macintosh microcomputer was used to present stimuli and record responses. An error was recorded each time a subject selected a pattern that was chosen previously within the block of 16 trials. Chance performance was estimated at 5.7 errors per 16 trials on the basis of a computer simulation.

Following this task, subjects were given a two-alternative, forced-choice recognition memory test for the 16 patterns used in the self-ordered pointing task. Each of the 16 patterns was printed on an index card and paired with a new pattern. Subjects were asked to identify for each pair the pattern that had been used in the self-ordered pointing task.

Results

The results of the self-ordered pointing task are shown in Panel A of Figure 2. Overall, there was a significant effect of age, $F(2, 65) = 7.6$, $p < .01$. Pairwise comparisons showed that the young subjects performed significantly better than the subjects in their sixties, who performed

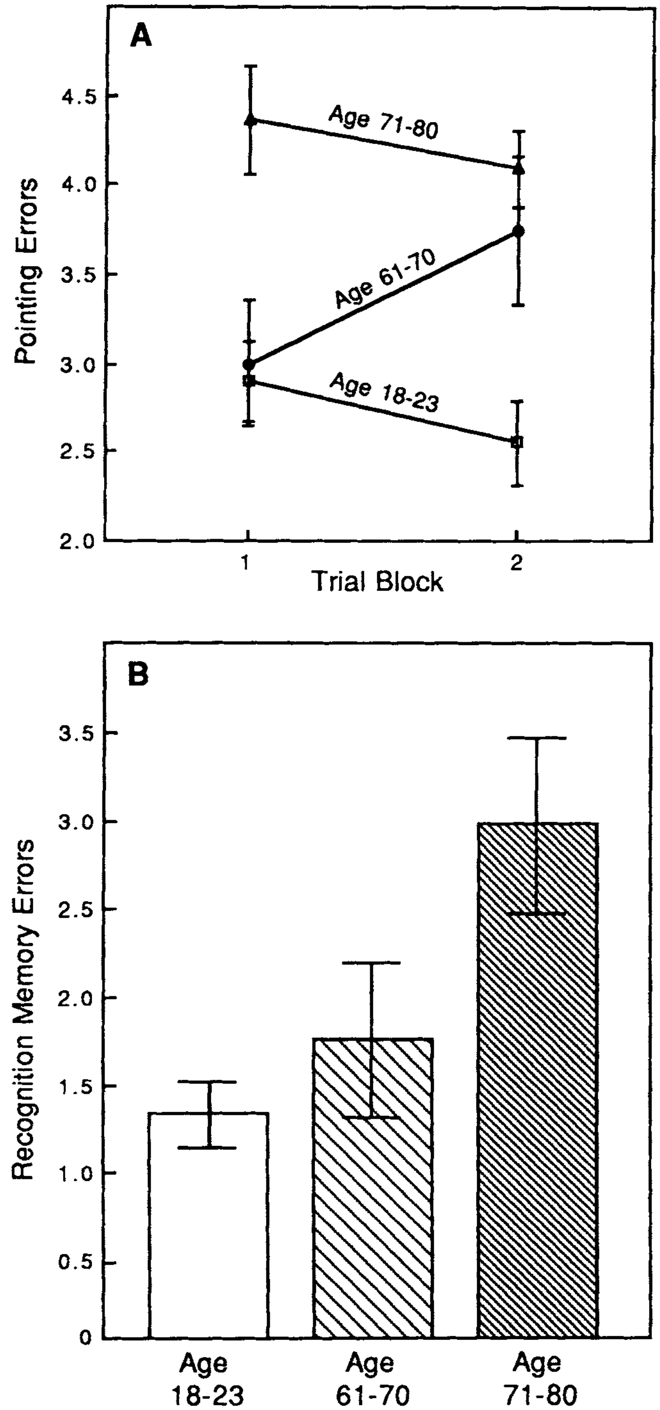

Figure 2. Panel A: Data from the self-ordered pointing task for young subjects (aged 18–23 years), subjects in their sixties (aged 61–70 years), and subjects in their seventies (aged 71–80 years). Note particularly the memory interference effects observed across blocks for subjects aged 61 to 70 years (chance estimated at 5.7 errors on the basis of a computer simulation). Panel B: Data from two-choice recognition memory test. Note the significant impairment in recognition memory in subjects aged 71 to 80 years (chance = 8 errors).

significantly better than the subjects in their seventies ($ps < .05$). There was also a significant Block × Age Group interaction, $F(2, 65) = 3.2, p < .05$, which indicated that the pattern of performance across the two blocks of trials was different for the different age groups. Specifically, the subjects in their sixties performed as well as the young subjects on the first block of trials, yet they performed more poorly than the young subjects on the second block of trials ($p < .05$). The subjects in their seventies committed more errors than either the young subjects or the subjects in their sixties on both blocks of trials.

There was also a significant effect of age, $F(2, 66) = 5.6, p < .01$, on the recognition test for previously presented patterns (see Panel B of Figure 2). Pairwise comparisons indicated no significant difference between the young subjects and the subjects in their sixties, $t(56) = 0.43, p = .30$. However, the subjects in their seventies exhibited significant recognition memory impairment compared with the young control subjects and the subjects in their sixties ($ps < .03$).

Discussion

The results demonstrate age-related impairment on a test sensitive to frontal lobe dysfunction (the self-ordered pointing task) and on a test sensitive to medial temporal lobe dysfunction (the recognition memory test). The age-related impairment on the self-ordered pointing test suggests a pattern of impairment consistent with a deficit in working memory, perhaps because of increased memory interference. For example, subjects in their sixties initially performed as well as young subjects on the self-ordered pointing task but then exhibited significant impairment on the second block of trials. Thus, subjects in their sixties appeared to exhibit a failure in distinguishing responses made during the first block of trials from those made during the second block. In other words, these subjects exhibited heightened proactive interference due to the previous presentation of the same stimuli on an earlier block of trials.

It is likely that performance on the self-ordered pointing task depends not only on working memory but also on general recognition memory for the patterns. However, the impaired performance on the self-ordered pointing task by subjects in their sixties could not be attributed to gross deficits in recognition memory. A recognition memory impairment would have affected performance on the first block of trials at least as much as it would have affected performance on the second block of trials. In addition, these same subjects performed as well as young subjects on a subsequent recognition memory test of the stimulus patterns. Thus, the impairment observed in subjects in their sixties suggests a problem in working memory in which subjects must overcome proactive interference while performing the task.

The subjects in their seventies exhibited a more pervasive cognitive impairment than that exhibited by subjects in their sixties. First, the subjects in their seventies exhibited problems within the first block of trials of the self-ordered pointing task. Apparently, these subjects failed to monitor responses even within a block of trials. This pattern of impairment is similar to that observed in patients with frontal lobe lesions (see Petrides & Milner, 1982). Moreover, the subjects in their seventies exhibited significant impairment in a subsequent recognition memory test of the stimulus patterns. The subjects in their seventies, however, did not exhibit increased errors across the two blocks of trials.

Two factors may have contributed to the failure to observe increased errors across the two blocks of trials in the group of subjects in their seventies. First, performance by these subjects on the first block of trials was so poor that their performance was close to chance performance. Indeed, the level of performance on the first block of trials was only 1.3 errors less than chance performance. Thus, an even greater deficit by these subjects may not have been observed on the second block because of floor effects. Another possibility is that the significant recognition memory impairment exhibited by these subjects reduced proactive interference across blocks of trials. That is, a decrease in recognition memory for the stimuli themselves would limit the effect that stimuli in the first block of trials would have on responses during the second block of trials.

The age-related deficit in monitoring observed on the self-ordered pointing task is in accord with studies by Hasher and colleagues (Hartman & Hasher, 1991; Hasher, Stoltzfus, Zacks, & Rypma, 1991; Hasher & Zacks, 1988) on tests of inhibitory control. In these studies, older adults had difficulty inhibiting irrelevant information on tasks involving selective attention or memory. The present findings are also consistent with earlier findings of increased proactive interference on standard tests of paired-associate learning (for a review, see Kausler, 1991). Furthermore, the findings are in accord with neuropsychological findings of impaired monitoring or inhibitory control in patients with frontal lobe lesions. For example, patients with frontal lobe lesions exhibit increased interference on the Stroop test (Perret, 1974), a test in which subjects must ignore color words and respond to the ink color in which the words are presented (e.g., the word *red* printed in blue ink). Problems in inhibitory control or monitoring may also be involved in other deficits associated with frontal lobe function, such as deficits in planning, problem solving, and metamemory (for further discussion, see Shimamura, in press).

The present findings are also consistent with neuropathological studies of age-related biological changes (for reviews, see Petit, 1982; Rapp & Amaral, 1992). For example, across the adult life span the amount of atrophy observed in the frontal lobes is greater than that observed in any other cortical region (Haug et al., 1983). In addition, significant pathology, such as the occurrence of senile plaques, occurs prominently in the medial temporal lobe, especially in the hippocampal formation (Meencke, Ferszt, Gertz, & Cervos-Navarro, 1983). Finally, recent in vivo neuroimaging studies using magnetic resonance imaging indicate age-related changes in the frontal and medial temporal lobes (Jernigan et al., 1991; Lim, Zipursky, Watts, & Pfefferbaum, 1992).

In conclusion, the findings suggest that age-related deficits occur both in working memory and in recognition memory. Specifically, individuals in their sixties exhibited deficits in the self-ordered pointing test but not on the recognition memory test, whereas individuals in their seventies exhibited deficits in both tests. The findings may provide information concerning the time course of age-related cognitive decline. That is, the findings suggest that working memory deficits occur earlier than deficits in recognition memory. To the extent that these measures are behavioral markers for neural systems, the findings suggest that in the normal aging process cognitive deficits associated with frontal lobe dysfunction precede those associated with medial temporal dysfunction. Further investigations are necessary to determine if this interpretation is plausible or if the findings are due simply to differences in test sensitivity or measurement artifacts. The hypothesis that frontal lobe function might age faster than medial temporal function offers interesting research prospects on both behavioral and neurobiological fronts.

References

Albert, M. S., & Kaplan, E. (1980). Organic implications of neuropsychological deficits in the elderly. In L. W. Poon, J. L. Fozard, L. S. Cermak, D. Arenberg, & L. W. Thompson (Eds.), *New directions in memory and aging: Proceedings of the George A. Talland Memorial Conference* (pp. 403–432). Hillsdale, NJ: Erlbaum.

Albert, M. S., & Moss, M. B. (Eds.). (1988). *Geriatric neuropsychology.* New York: Guilford Press.

Baddeley, A. (1986). *Working memory.* Oxford, England: Oxford University Press.

Butters, N. (1980). Potential contributions of neuropsychology to our understanding of the memory capacities of the elderly. In L. W. Poon, J. L. Fozard, L. S. Cermak, D. Arenberg, & L. W. Thompson (Eds.), *New directions in memory and aging: Proceedings of the George A. Talland Memorial Conference* (pp. 451–459). Hillsdale, NJ: Erlbaum.

Comalli, P. E., Jr., Wapner, S., & Werner, H. (1962). Interference effects of Stroop Color–Word Test in childhood, adulthood, and aging. *Journal of Genetic Psychology, 100,* 47–53.

Craik, F. I. M. (1977). Age differences in human memory. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (pp. 384–420). New York: Van Nostrand Reinhold.

Goldman-Rakic, P. S. (1987). Circuitry of primate prefrontal cortex and regulation of behavior by representational memory. In F. Plum (Ed.), *Handbook of physiology: The nervous system* (Vol. 5, pp. 373–417). Bethesda, MD: American Physiological Society.

Hartman, M., & Hasher, L. (1991). Aging and suppression: Memory for previously relevant information. *Psychology of Aging, 6,* 587–594.

Hasher, L., Stoltzfus, E. R., Zacks, R. T., & Rypma, B. (1991). Age and inhibition. *Journal of Experimental Psychology: Learning, Memory and Cognition, 17,* 163–169.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation* (pp. 193–225). San Diego, CA: Academic Press.

Haug, H., Barnwater, U., Eggers, R., Fischer, D., Kuhl, S., & Sass, N. L. (1983). Anatomical changes in aging brain: Morphometric analysis of the human prosencephalon. In J. Cervos-Navarro & H. I. Sarkander (Eds.), *Brain aging: Neuropathology and neuropharmacology* (pp. 1–12). New York: Raven Press.

Janowsky, J. S., Shimamura, A. P., & Squire, L. R. (1989). Source memory impairment in patients with frontal lobe lesions. *Neuropsychologia, 27,* 1043–1056.

Janowsky, J. S., & Thomas-Thrapp, L. J. (1993). Complex figure recall in the elderly: A deficit in memory or construction strategy? *Journal of Clinical and Experimental Neuropsychology, 15,* 159–169.

Jernigan, T. L., Archibald, S. L., Berhow, M. T., Sowell, E. R., Foster, D. S., & Hesselink, J. R. (1991). Cerebral structure on MRI. 1. Localization of age-related changes. *Biological Psychiatry, 29,* 55–67.

Kausler, D. H. (1991). *Experimental psychology, cognitive, and human aging* (2nd ed.). New York: Springer-Verlag.

Light, L. L., & Burke, D. M. (1988). *Language, memory, and aging.* New York: Cambridge University Press.

Lim, K. O., Zipursky, R. B., Watts, M. C., & Pfefferbaum, A. (1992). Decreased gray matter in normal aging: An in vivo magnetic resonance study. *Journal of Gerontology: Biological Sciences, 47,* B26–B30.

McIntyre, J. S., & Craik, F. I. M. (1987). Age differences in memory for item and source information. *Canadian Journal of Psychology, 42,* 175–192.

Meencke, H. J., Ferszt, R., Gertz, H. J., & Cervos-Navarro, J. (1983). Hippocampal pathology in normal aging and dementia. In J. Cervos-Navarro & H. I. Sarkander (Eds.), *Brain aging: Neuropathology and neuropharmacology* (pp. 13–26). New York: Raven Press.

Milner, B., Petrides, M., & Smith, M. L. (1985). Frontal lobes and the temporal organization of memory. *Human Neurobiology, 4,* 137–142.

Moscovitch, M., & Winocur, G. (1992). The neuropsychology of memory and aging. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 315–372). Hillsdale, NJ: Erlbaum.

Naveh-Benjamin, M. (1990). Coding of temporal order information: An automatic process? *Journal of Experimental Psychology: Learning, Memory and Cognition, 16,* 117–126.

Obler, L. K., & Albert, M. L. (1985). Language skills across adulthood. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (pp. 463–473). New York: Van Nostrand Reinhold.

Perret, E. (1974). The left frontal lobe of man and the suppression of habitual responses in verbal categorical behavior. *Neuropsychologia, 12,* 323–330.

Petit, T. L. (1982). Neuroanatomical and clinical neuropsychological changes in aging and senile dementia. In F. I. M. Craik & S. Trehub (Eds.), *Aging and cognitive processes: Advances in the study of communication and affect* (Vol. 8, pp. 1–21). Hillsdale, NJ: Erlbaum.

Petrides, M., & Milner, B. (1982). Deficits on subject-ordered tasks after frontal- and temporal-lobe lesions in man. *Neuropsychologia, 20,* 249–262.

Rapp, P. R., & Amaral, D. G. (1992). Individual differences in the cognitive and neurobiological consequences of normal aging. *Trends in Neuroscience, 15,* 340–345.

Salthouse, T. (1991). *Theoretical perspectives on cognitive aging.* Hillsdale, NJ: Erlbaum.

Schaie, K. W. (1990). The optimization of cognitive functioning in old age: Predictions based on cohort-sequential and longitudinal data. In P. B. Baltes & M. M. Baltes (Eds.), *Successful aging: Perspectives from the behavioral sciences* (pp. 94–117). Cambridge, England: Cambridge University Press.

Shimamura, A. P. (1990). Aging and memory disorders: A neuropsychological analysis. In M. L. Howe, M. J. Stones, & J. Brainerd (Eds.), *Cognitive and behavioral performance factors in atypical aging* (pp. 37–65). New York: Springer-Verlag.

Shimamura, A. P. (in press). Memory and frontal lobe function. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences.* Cambridge, MA: MIT Press.

Shimamura, A. P., Janowsky, J. S., & Squire, L. R. (1990). Memory for the temporal order of events in patients with frontal lobe lesions and amnesic patients. *Neuropsychologia, 28,* 803–813.

Shimamura, A. P., Janowsky, J. S., & Squire, L. R. (1991). What is the role of frontal lobe damage in amnesic disorders? In H. S. Levin, H. M. Eisenberg, & A. L. Benton (Eds.), *Frontal lobe function and dysfunction* (pp. 173–195). New York: Oxford University Press.

Stuss, D. T., & Benson, D. F. (Eds.). (1986). *The frontal lobes.* New York: Raven Press.

Whelihan, W. M., & Lesher, E. L. (1985). Neuropsychological changes in frontal function with aging. *Developmental Psychology, 1,* 371–380.

Received December 6, 1992
Revision received July 20, 1993
Accepted September 8, 1993 ■