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Neuropsychological perspectives on memory and cognitive decline in normal human aging

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Evidence from both neuropsychological and cognitive research suggest that age-related changes in human memory and cognition are multifaceted. Three domains of cognition—cognitive slowing, working memory, and new learning ability—are reviewed. These domains incur prominent declines during the course of human aging. Based on neuropsychological findings, three aspects of biological aging—general neuronal efficacy, frontal lobe function, medial temporal lobe function—are thought to mediate the three respective domains of cognitive changes. It is suggested that these three and other domains of cognition may decline with age, but which and to what extent deficits arise in older individuals is quite variable.

Key words: human / aging / memory / cognition / neuropsychology

AS WE AGE, MEMORY and cognitive abilities are influenced by a myriad of factors—including genetic, experiential, health, personality and cultural factors. Scientific investigations of human aging have been complicated by these diverse influences. Indeed, many studies of cognitive aging reveal enormous variability among older adults, such that some older adults exhibit only mild changes, whereas others exhibit significant and sometimes debilitating deficits.[1-3] Some of this variability may be attributed to the diversity of experiential and cultural factors that influence behavior (e.g. educational level, lifestyle). Yet, even measures of neurobiological change, such as cortical atrophy and ventricular enlargement, increase in variability among older adults.[4]

Analyses of differential patterns of aging may be facilitated by research in cognitive neuropsychology. In this scientific endeavor, findings from neurological and neuroimaging research are used to help characterize aspects of cognitive function, such as perception, attention, memory, and language. For instance, studies of neurological patients indicate that damage to different brain regions disrupts memory performance in qualitatively different ways.[5,6] Also, recent neuroimaging research [e.g. magnetic resonance imaging (MRI), positron emission tomography (PET)] have identified regional specificity of cognitive function from both anatomical and physiological perspectives. These findings provide useful information about the organization of neural systems, and as a result, they may help characterize different aspects of age-related changes.

A rather simple view of cognitive aging is proposed. It is suggested that mental performance depends upon many aspects of cognitive function and that time (ie. aging) increases the probability that some aspects will become impaired. Thus, a decline in performance with age may not be attributable to impairment in any single cognitive function, but rather it may be associated with a variety of factors. Based on this simple view, the particular aspect of cognitive function that is affected may be different among older individuals. By analogy, human aging may be viewed just as one might view aging in mechanical devices, such as cars. One might expect declines in road performance in older cars, but one would not expect each car to exhibit the same mechanical dysfunction. Poor performance may be a function of many factors—such as a faulty engine, transmission or electrical system, and any one or a number of these factors could be the cause of poor performance in any given car. In terms of human aging, a decline in cognitive performance in older adults is probably not attributable to impairment in any particular cognitive function, but rather it is likely to be a function of many factors, and any one or a number of them could be the cause of poor performance in any given individual. It may even be that some mechanical components are more fragile than others. Likewise, some cognitive components may be more sensitive to aging than others.

This article reviews memory and cognitive changes associated with normal human aging. Evidence from

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both aging and neuropsychological research will be described with reference to three areas of cognition: (1) general cognitive slowing; (2) attention and working memory; and (3) new learning ability. These areas experience some of the most significant age-related changes during adulthood.[3,7-8] They are analyzed both in terms of functional properties and in terms of their underlying neural substrates.

Cognitive slowing

Slowing of reaction time (RT) is perhaps the most frequently observed change associated with adult aging. To provide a perspective on the magnitude of this change, in one study, academic professors between the ages of 31 and 70 exhibited response slowing on the order of 3.9 ms per year.[9] Response slowing can be observed under a variety of task variables, such as manipulations in the number of decision choices, the type of stimulus material (e.g. verbal vs visual), and the type of response mode (e.g. voice vs manual). Indeed, some have proposed that response slowing is the primary cause of many if not all age-related cognitive deficits.[10-13] Such proposals have gained increasing support in recent analyses.[11,12]

Studies of reaction time have shown that slowing in the elderly has a central or cognitive component as opposed to a purely motor locus.[14] For example,

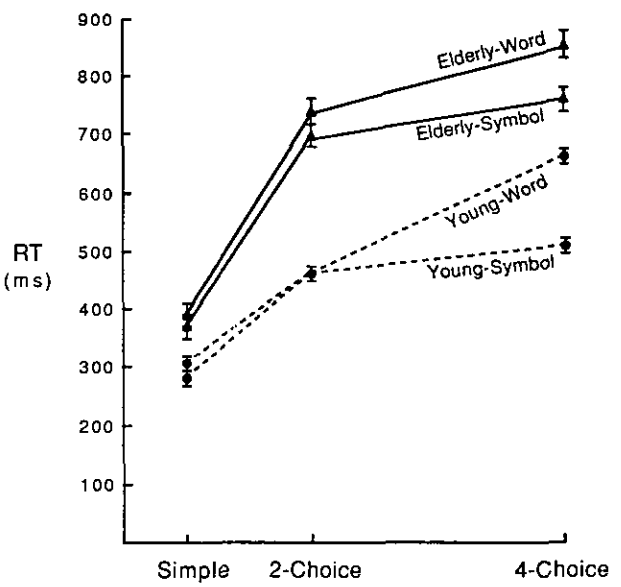

Figure 1. Simple and two- and four-choice reaction time to word stimuli and pictorial symbols for elderly (—) and young subjects (---).

the difference between young and older adults on tests of choice RT increases as the number of response choices increases. Figure 1 illustrates this phenomenon. Young (age 18-22) and elderly (age 60-80) subjects were administered three RT tasks: simple; two-choice; and four-choice RT tasks.[15] Each task was tested using either word or symbolic stimuli (e.g. arrows). In the simple RT task, subjects simply hit a key when the word 'go' or a symbol of a traffic light was presented on a computer monitor. In the two-choice task, subjects hit one of two keys depending on the word or arrow that was presented (left or right); and in the four-choice task, subjects hit one of four keys depending upon the word or arrow that was presented (left, right, up or down). Elderly subjects exhibited overall slowed RTs. For both elderly and young subjects, RTs to symbolic stimuli (e.g. arrows) were faster than RTs for word stimuli. Note, however, that the effect of age increased with the number of choices, despite the fact that the motor output (i.e. single keypress) remained constant. Thus, slowing of cognitive analysis and decision making, and not simply motor slowing, contributed significantly to response slowing. Various studies have shown that response latency in older adults increases with other manipulations of task difficulty or task complexity.[16,17]

Recent analyses of RT have suggested a reliable relationship between RTs of older adults and those of young adults. Specifically, under a variety of conditions RTs exhibited by older adults appear to be proportional to RTs exhibited by young adults. Brinley[16] was the first to characterize response slowing in terms of a proportionate increase in RTs. He illustrated this relationship by plotting RTs of young subjects in a given task condition with RTs of older subjects in the same condition. These plots are now called Brinley plots. For example, in Figure 2 the data from each of the conditions in Figure 1 are graphed in a Brinley plot. For each condition, one data point represents the mean RTs by young subjects (x-axis) plotted against mean RTs by older subjects (y-axis). Note that RTs by older adults increase proportionately with that of young adults. As a result, the findings can be described as a linear function in which the magnitude of slowing is represented by the slope of the linear relationship. In this case, the RTs of older adults are 1.40 items larger than RTs of young adults.

Findings of a proportionate factor associated with response slowing suggest a powerful yet simple interpretation of age-related deficits. That is,

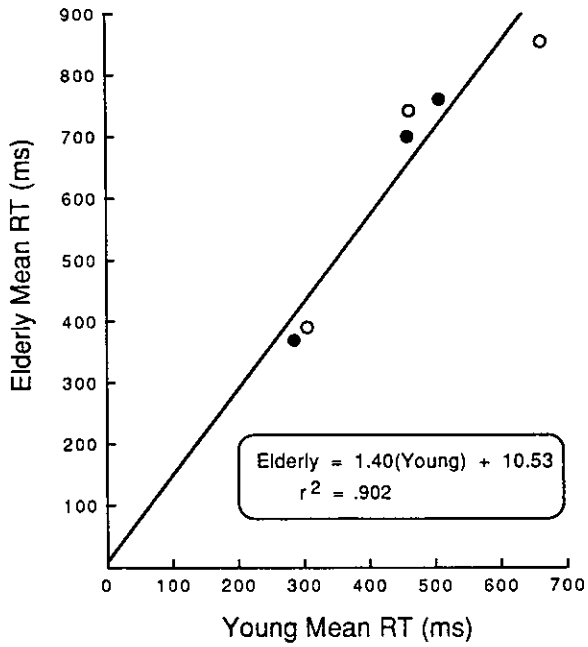

Figure 2. Brinley plot showing mean RTs by elderly subjects in each condition presented in Figure 1 plotted against mean RTs by young subject (●, symbol conditions; ○, word conditions). Note that the relationship between young and elderly performance conformed well to a linear function ($r^2 = 0.902$).

response slowing may provide an index of generalized biological aging, in which many if not all cognitive functions degrade to some (proportionate) degree in older adults. In terms of the car analogy, all components may be affected by a general degradative process, such as rust*. Generalized cognitive slowing in aging may reflect a global loss of neuronal efficacy that affects many neural systems.[10,12,17] Recently, there has been some disagreement raised concerning the degree to which analyses from Brinley plots support a general 'rust' factor associated with aging.[18] Yet, the pervasive linear relationship in RT tasks between young and older adults suggest that, to some degree, aging affects many aspects of cognitive function. It is important to note that a general factor, such as neuronal efficacy, does not necessarily preclude the possibility that, in some cognitive domains, certain components are particularly or disproportionately affected by aging.

*The notion of rust in this car metaphor is simply meant to be *analogous* to degradative processes that may occur in the nervous system. However, the similarity between rust and actual oxidative degradation is thought provoking.

That is, it appears that generalized slowing cannot fully account for all age-related cognitive changes. Indeed, the following sections suggest that both working memory and new learning ability are cognitive domains in which particularly large aging effects have been observed.

Age-related changes in attention and working memory

The term, working memory, refers to the memory component involved with the on-line manipulation of information. In anthropomorphic terms, this component acts as an executive or supervisor who controls and organizes information to be encoded, stored, or retrieved. Baddeley[19] identified three subcomponents of working memory—an executive control, a short-term memory buffer for phonological information, and a short-term memory buffer for visuospatial information. The executive control component of working memory is closely related to the notion of selective attention. Indeed, executive control may be viewed as the cognitive function that controls the focus of attention to specific perceptions or memories. Thus, executive control and its associated memory buffers can be used for the brief maintenance of information in memory (i.e. short-term memory). Using animal models of working memory, Fuster[20] and Goldman-Rakic[21] have demonstrated that certain cortical neurons in the prefrontal cortex appear to hold or maintain neural activity immediately after the offset of a stimulus. This process may be central to working memory in that it may reflect cognitive control and active short-term memory buffers. Recent PET studies of humans engaged in a visual short-term memory task reveal similar activations in regions within prefrontal and parietal cortex.[22]

Another central feature of working memory is the ability to gate or filter extraneous information. Shimamura[23] suggests that this gating activity may play a prominent role in executing selective attention. Others have suggested similar working memory processes involving inhibitory control mechanisms.[24-26] Various tests have been used to assess the ability to filter extraneous information. For example, the Stroop test[27,28] has been used to assess the influence of irrelevant verbal information. In this test, subjects are asked to report the ink color of stimuli (e.g. color patch or a word written in colored ink). Response times are slowed when the stimuli

are conflicting color names (e.g. the word blue written in red ink). Another method of testing inhibitory control is the negative priming paradigm developed by Tipper.[29] In this test, subjects are given trials in which they attend to a certain stimulus in the presence of another stimulus that is to be ignored. For example, subjects may be asked to report on each trial the letter that is printed in green and to ignore the letter printed in yellow. Response times are slowed when an ignored stimulus on one trial becomes the attended stimulus on the next trial. Findings of 'negative priming' suggest that ignored stimuli are actively inhibited or disengaged from response programs and that this inhibition must be overcome if the stimulus is to be acted upon in the subsequent trial. The Stroop and negative priming paradigm offer useful methods by which to analyze the role of working memory in filtering or gating of interfering or extraneous information.

Neuropsychological evidence suggests that the prefrontal cortex contributes significantly to working memory. For example, patients with frontal lobe lesions exhibit impairment on tests of short-term memory (e.g. digit span), selective attention, and Stroop interference.[30-32] Classic findings have indicated that patients with frontal lobe lesions exhibit impairment in a variety of executive or supervisory functions, such as planning, organization of information, and problem solving.[32-34] Moreover, recent findings suggest that patients with frontal lobe lesions exhibit greater susceptibility to interference on tests of paired-associate learning. In one study, initial learning of a word pair (.e.g LION-HUNTER) was not impaired in patients with frontal lobe lesions.[35] However, subsequent learning of similar pairs (e.g. LION-CIRCUS) was severely disrupted, because learning involved the suppression of a prior, now irrelevant, memory association. Apparently, the frontal lobes act to filter extraneous memory information as well as perceptual information.

Recently, a great deal of research has been devoted to age-related changes in working memory functions. Much of this research has been stimulated by Hasher and Zacks[26] in their suggestion that age-related changes in memory and cognition are mediated by decrements in the ability to inhibit extraneous information processing. Aging prominently affects a variety of attention and working memory functions, including heightened interference effects on a variety of tests, including the Stroop test and tests of paired-associate learning.[36-38] In addition to these effects of heightened interference, analyses of the negative priming effect indicate that older adults fail to inhibit irrelevant information and thus exhibit little or no negative priming effect on a subsequent trial.[39-40] Interestingly, the failure to exhibit negative priming across trials has been shown to be correlated with the degree to which response times are slowed by irrelevant information presented within the same trial.[40] These findings suggest that older adults have particular difficulty in gating or inhibiting irrelevant information.

Working memory has been analyzed during problem solving tasks requiring extensive on-line manipulation of information.[41,42] In these studies, aging effects are prominent when the demands of search and retrieval processes are high. A simple and common experience of such problems is word finding or the inability to retrieve a specific name of a person or concept. Problems of word finding and the related tip-of-the-tongue phenomenon, involve working memory processes that facilitate the search and retrieval of information stored in memory. Neuropsychological findings suggest that such 'anomic' deficits can occur as a result of pathology in various cortical regions, including anterior and posterior associational areas. However, the pattern of word finding problems observed in older adults appear to resemble most closely the pattern of anomia observed in patients with frontal lobe pathology. In these patients, and in older adults, the deficit appears to be related to a problem in the association between semantic knowledge and a phonological code or referent (e.g. what's the person's name?) rather than a problem in semantic knowledge, *per se* (e.g. do I know this person?).[32,43] In sum, the variety of age-related changes in working memory implicate frontal lobe dysfunction.

New learning ability

During the past three decades, a significant amount of neuropsychological research has been devoted to the biological basis of new learning ability. This research has focused on the prominent role of the medial temporal lobe in memory. Patients with lesions in this area exhibited a profound impairment of new learning ability—that is, they are unable to remember events and information encountered since the onset of amnesia.[5,6] Despite severe impairment of new learning ability, patients with circumscribed medial temporal lesions do not exhibit detectable impairment in other mental abilities, such as

intellectual or language disorders. Research on amnesic patients suggest that the medial temporal region is critical for the establishment of long-term memory.

An important finding from studies of amnesia is that not all aspects of learning and memory are impaired. Indeed, some aspects, such as working memory (e.g. digit span), priming effects, and simple forms of skill learning are preserved in patients with medial temporal lesions. For example, in studies of priming effects, amnesic patients exhibit normal expressions of memory when tested in an indirect or implicit fashion.[44,45] In one study,[46] amnesic patients and control subjects exhibited equivalent levels of priming when presented words for study (e.g. MOTEL) and then asked to say the first word to come to mind when shown three-letter beginnings of words (e.g. MOT). Amnesic patients also exhibit normal learning on skill learning tasks, such as the pursuit-rotor task, in which subjects learn to keep a stylus pointed onto a rotating target. Such skills can be performed by amnesic patients as well as control subjects, even after a delay of days or weeks.[47] Also, amnesic patients exhibit normal expression of classical conditioning of the eyeblink response.[47,48] These findings indicate that the medial temporal region does not participate in memory functions required for the expression of priming effects, skills and classical conditioning.

Various terms have been used to describe the memory component that is impaired in amnesia. For example, it has been suggested that the medial temporal region is part of a neural system critical for the establishment of a particular kind of learning, one that has been described as declarative or explicit memory.[6,44,49] The term, relational memory has also been used to describe this form of memory, because recent findings from both animal and human studies suggest that a prominent feature of this process is the binding of new information to existing memory.[50,51] In human studies, the amnesic deficit appears to reflect a failure to relate or incorporate recent memories of facts and events with existing memory representations.

Alzheimer's disease is another neurological disorder that can cause medial temporal pathology and, as a result, impair new learning ability.[52] In Alzheimer's disease, impairment of new learning ability is often the outstanding deficit associated with early stages of this disease; yet, even at mild and moderate stages of Alzheimer's disease, patients exhibit a wide array of other cognitive deficits, including problems in attention, language, and intellectual function.[53] Moreover, unlike patients with circumscribed medial temporal pathology, Alzheimer's disease affects other nondeclarative memory functions, such as priming effects.[54] Neuropathological studies of Alzheimer's disease indicate severe and extensive cortical damage, though medial temporal areas appear to be particularly affected.[55] Thus, pathological evidence is consistent with the rather diffuse nature of cognitive and memory deficits associated with this disease.

Complaints about poor learning and memory are frequent among older adults. Many adults beyond the age of 60 notice particular problems remembering recent events and information.[56,57] Such findings have demonstrated age-related declines on a variety of memory tests, including tests of verbal and nonverbal free recall, cued recall, paired-associate learning, and recognition memory. It should be noted, however, that aging deficits are extremely mild compared to deficits observed in amnesic patients. Also, aging appears to affect some aspects of memory more than others. For example, free recall performance often appears more impaired than recognition memory performance.[58]

These findings implicate medial temporal dysfunction as a contributor to at least some of the age-related changes in learning and memory. It is misleading, however, to suggest that all age-related learning deficits are attributed to medial temporal dysfunction. For example, deficits in skill learning and classical conditioning have been observed in elderly individuals.[59] Also, evidence suggests that priming effects are affected in older adults, though these effects are relatively small compared to deficits on standard tests of 'declarative' memory.[60,61] Since deficits on tests of priming, skill learning and classical conditioning are not generally observed in amnesic patients, findings of age-related changes on these measures suggest that brain regions in addition to the medial temporal lobe are compromised in normal aging.

Another prevalent memory disorder observed in older adults is source memory impairment. In everyday experiences of this anomaly, individuals remember some factual information (e.g. recommendation of a good movie, interesting research finding), but they forget the source of the information (e.g. who provided the information) or the time and place the information was mentioned. Although medial temporal pathology would affect source memory just as it affects other kinds of explicit

memories,[62,63] neuropsychological evidence suggests that frontal lobe dysfunction particularly affects source memory.[64] In terms of aging, older adults often exhibit problems in source memory, and these memory problems are out of proportion to problems in the ability to remember factual information.[64-66] In studies of aging, source memory deficits have been correlated with other measures of frontal lobe dysfunction.[67,68]

Summary

As indicated by the scope of memory and cognitive changes associated with aging, it is evident that deficits cannot be attributed to any single cognitive or biological component. When findings from aging research are integrated with neuropsychological findings, it appears that both frontal and medial temporal regions contribute significantly to age-related changes. For example, problems in attention, working memory, word finding, and source memory may be, in part, related to frontal lobe function. The behavioral findings are consistent with neuropathological findings of disproportionate neuronal atrophy in the frontal lobe in normal aging.[69] Problems in new learning ability are likely to be related to medial temporal dysfunction. In normal aging, this brain region also exhibits significant neuropathological abnormalities, such as increases in the preponderance of amyloid plaques.[70]

In addition to age-related changes in frontal and medial temporal regions, one must still consider more general changes in neuronal efficacy that pervade many if not all neural systems. It is expected that during the course of six decades of use, the human nervous system loses general efficiency. Global neurobiological changes, such as reduced blood flow, inability to prevent damage from oxidation, and poor metabolic uptake may account for general losses of neuronal efficacy. Such changes may account for the pervasive findings of cognitive slowing in older individuals. Based on a neuropsychological perspective and the view that aging effects are multivariate, future progress in research, such as advances in neuroimaging technology, may provide clearer links between behavioral and biological changes associated with normal aging. For example, biological changes in different neural systems may have different time courses. Also, some individuals may be more susceptible to medial temporal changes whereas others may be more susceptible to frontal lobe changes. Finally, based on a better understanding of age-related cognitive changes, it may be possible to develop methods—perhaps psychological or pharmacological methods—by which typical age-related changes are mitigated or eliminated.

References

1. Heron A, Chown S (1967) Age and Function. Little and Brown, Boston
2. Morse CK (1993) Does variability increase with age? An archival study of cognitive measures. Psychol Aging 8: 156-164
3. Shimamura AP (1990) Aging and memory disorders: a neuropsychological analysis, in Cognitive and Behavioral Performance Factors in Atypical Aging (Howe ML, Stones MH, Brainerd CJ, eds), pp 37-65. Springer, New York
4. Pfefferbaum A, Zatz LM, Jernigan TL (1986) Computer-interactive method for quantifying cerebrospinal fluid and tissue in brain CT scans: effects of aging. J Computed Assisted Tomography 10:571-578
5. Shimamura AP (1989) Disorders of memory: the cognitive science perspective, in Handbook of Neuropsychology (Boller F, Grafman J, eds), pp 35-73. Elsevier Science, Amsterdam
6. Squire LR (1987) Memory and Brain. Oxford University Press, New York
7. Albert MS, Moss MB (eds) (1988) Geriatric Neuropsychology. Guilford Press, New York
8. Moscovitch M, Winocur G (1992) The neuropsychology of memory and aging, in The Handbook of Aging and Cognition (Craik FIM, Salthouse TA, eds), pp 315-372. Erlbaum Associates, Hillsdale, NJ
9. Shimamura AP, Berry JM, Mangels JA, Rusting CL, Jurica PJ (in press) Memory and cognitive abilities in academic professors: evidence for successful aging. Psychol Sci
10. Birren JE (1965) Age changes in speed of behavior: its central nature and physiological correlates, in Behavior, Aging, and the Nervous System (Welford AT, Birren JE, eds), pp 191-216. Charles C Thomas, Springfield
11. Cerella J (1985) Information processing rates in the elderly. Psychol Bull 98:67-83
12. Welford AT (1958) Ageing and Human Skill. Oxford University Press, London
13. Myerson J, Ferraro FR, Hale S, Lima SD (1992) General slowing in semantic priming and word recognition. Psychol Aging 7:257-270
14. Botwinick J (1984) Aging and Behavior, 3rd edn. Springer, New York
15. Shimamura AP, Mangels JA, Jurica PJ (1994) Reaction time to verbal and pictorial stimuli in older adults and patients with frontal lobe lesions. Submitted
16. Brinley JF (1965) Cognitive sets, speed and accuracy of performance in the elderly, in Behavior, Aging and the Nervous System (Welford AT, Birren JE, eds), pp 114-149. Springer, Springfield
17. Salthouse TA, Somberg GL (1982) Isolating the age deficit in speeded performance. J Gerontol 37:59-63
18. Perfect TJ (1994) What can Brinley plots tell us about cognitive aging? J Gerontol: Psychol Soc 49:P60-P64
19. Baddeley A (1986) Working memory. Oxford University Press, Oxford
20. Fuster JM (1989) The Prefrontal Cortex, 2nd edn. Raven Press, New York

21. Goldman-Rakic PS (1987) Circuitry of primate prefrontal cortex and regulation of behavior by representational memory, in Handbook of Physiology: The Nervous System; Vol. 5 (Plum F, ed), pp 373-417). American Physiological Society, Bethesda
22. Jonides J, Smith EE, Koeppe RA, Awh E, Minoshima S, Mintun MA (1993) Spatial working memory in humans as revealed by PET. Nature 363:623-625
23. Shimamura AP (1994) Frontal lobes and memory, in The Cognitive Neurosciences (Gazzaniga MS, ed). MIT Press, Cambridge
24. Dempster FN (1992) The rise and fall of the inhibitory mechanism: toward a unified theory of cognitive development and aging. Dev Rev 12:45-75
25. Diamond A (1990) Developmental time course in human infants and infant monkeys, and the neural bases of inhibitory control in reaching, in The Development and Neural Bases of Higher Cognitive Function (Diamond A, ed), pp 637-676. Annals of the New York Academy of Sciences, New York
26. Hasher L, Zacks RT (1988) Working memory, comprehension, and aging: a review and a new view, in The Psychology of Learning and Motivation, Vol. 22 (Bower GH, ed), pp 193-225. Academic Press, San Diego
27. Stroop JR (1935) Studies of interference in serial verbal reactions. J Exp Psychol 18:643-662
28. MacLeod C (1991) Half a century of research on the Stroop effect: an integrative review. Psychol Bull 109:163-203
29. Tipper SR (1985) The negative priming effect: inhibition priming by ignored objects. Quart J Exp Psychol 37A: 571-590
30. Oscar-Berman M (1980) The neuropsychological consequences of long-term chronic alcoholism. Am Sci 68:410-419
31. Perret E (1974) The left frontal lobe of man and the suppression of habitual responses in verbal categorical behavior. Neuropsychologia 12:323-330
32. Shimamura AP, Janowsky JS, Squire LR (1991) What is the role of frontal lobe damage in amnesic disorders?, in Frontal Lobe Function and Dysfunction (Levin HS, Eisenberg HM, Benton AL, eds), pp 173-195. Oxford University Press, New York
33. Milner B (1964) Some effects of frontal lobectomy in man, in The Frontal Granular Cortex and Behavior (Warren JM, Akert K, eds), pp 313-334. McGraw-Hill, New York
34. Stuss DT, Benson DF (eds) (1986) The Frontal Lobes. Raven Press, New York
35. Shimamura AP, Mangels JA, Jurica PJ, Gershberg FB, Knight RT (1994) Susceptibility to memory interference effects following frontal lobe damage: findings from tests of paired-associate learning. J Cognit Neurosci, in press
36. Comalli PE, Wapner S, Werner H (1962) Interference effects of Stroop color-word test in childhood, adulthood, and aging. J Genet Psychol 100:47-53
37. Hartman M, Hasher L (1991) Aging and suppression: memory for previously relevant information. Psychol Aging 6:587-594
38. Kausler DH (1991) Experimental Psychology, Cognitive and Human Aging, 2nd edn. Springer, New York
39. Hasher L, Stoltzfus ER, Zacks RT, Rypma B (1991) Age and inhibition. J Exp Psychol: Learn Mem Cognit 17:163-169
40. Kane MJ, Hasher L, Stoltzfus ER, Zacks RT, Connelly SL (1994) Inhibitory attentional mechanisms and aging. Psychol Aging 9:103-112
41. Salthouse T (1991) Theoretical Perspectives on Cognitive Aging. Erlbaum, Hillsdale
42. Salthouse TA, Mitchell DR, Skovronek E, Babcock RL (1989) Effects of adult age and working memory on reasoning and spatial abilities. J Exp Psychol: Learn Mem Cognit 15:507-516
43. Burke D, MacKay DG, Worthley JS, Wade E (1991) On the tip of the tongue: what causes word finding failures in young and older adults? J Mem Lang 30:546-579
44. Schacter DL (1987) Implicit memory: history and current status. J Exp Psychol: Learn Cognit 13:501-518
45. Shimamura AP (1993) Neuropsychological analyses of implicit memory: Recent progress and theoretical interpretations in Implicit Memory: New Directions in Cognition, Development, and Neuropsychology (Graf P, Masson ME, eds). Erlbaum, Hillsdale
46. Graf P, Squire LR, Mandler G (1984) The information that amnesic patients do not forget. J Exp Psychol: Learn Mem Cognit 10:164-178
47. Parkin AJ (1982) Residual learning capability in organic amnesia. Cortex 18:417-440
48. Daum I, Channon S, Canavan AGM (1989) Classical conditioning in patients with severe memory problems. J Neurol Neurosurg Psychiat 52:47-51
49. Squire LR (1992) Memory and the hippocampus: a synthesis from findings with rats, monkeys, and humans. Psychol Rev 99:195-231
50. Eichenbaum H (1992) The hippocampal system and declarative memory in animals. J Cognit Neurosci 4:217-231
51. Rudy JW, Sutherland RJ (1992) Configural and elemental associations and the memory coherence problem. J Cognit Neurosci 4:208-216
52. Morris RG, Kopelman MD (1986) The memory deficits in Alzheimer-type dementia: a review. Quart J Exp Psychol 38 (A):575-602
53. Bayles KA, Kaszniak AW (1987) Communication and Cognition in Normal Aging and Dementia. Little and Brown, Boston
54. Shimamura AP, Salmon DP, Squire LR, Butters N (1987) Memory dysfunction and word priming in dementia and amnesia. Behav Neurosci 101:347-351
55. Price JL (1994) Tangles and plaques in healthy aging and Alzheimer's disease: Independence or interaction? Semin Neurosci 5:395-402
56. Craik FIM, Jennings JM (1992) Human memory, in The Handbook of Aging and Cognition (Craik FIM, Salthouse TA, eds), pp 51-110. Erlbaum, Hillsdale
57. Moscovitch M, Winocur G (1992) The neuropsychology of memory aging, in The Handbook of Aging and Cognition (Craik FIM, Salthouse TA, eds) pp 315-372. Erlbaum, Hillsdale
58. Craik FIM, McDowd JM (1987) Age differences in recall and recognition. J Exp Psychol: Learn Mem Cognit 13:474-479
59. Woodruff-Pak DS, Thompson RF (1988) Classical conditioning of the eyeblink response in the delay paradigm in adults aged 18-83 years. Psychol Aging 3:219-229
60. Light LL, Singh A (1987) Implicit and explicit memory in younger and older adults. J Exp Psychol: Learn Mem Cognit 13:531-541
61. Hultsch DF, Masson MEJ, Small BJ (1991) Adult age differences in direct and indirect tests of memory. J Gerontol: Psychol Sci 46:P22-30
62. Schacter DL, Harbluk J, McLachlan D (1984) Retrieval without recollection: an experimental analysis of source amnesia. J Verbal Learn Verbal Behav 23:593-611
63. Shimamura AP, Squire LR (1987) A neuropsychological study of fact memory and source amnesia. J Exp Psychol: Learn, Mem Cognit 13:464-473
64. Janowsky JS, Shimamura AP, Squire LR (1989) Source memory impairment in patients with frontal lobe lesions. Neuropsychologia 27:1043-1056

65. McIntyre JS, Craik FIM (1987) Age differences in memory for item and source information. Can J Psychol 42:175-192
66. Schacter DL, Osowiecki D, Kaszniak AW, Kihlstrom JF, Valdiserri M (1994) Source memory: extending the boundaries of age-related deficits. Psychol Aging 9:81-89
67. Craik FIM, Morris LW, Morris RG, Loewen ER (1990) Relations between source amnesia and frontal lobe functioning in older adults. Psychol Aging 5:148-151
68. Spencer WD, Raz N (1994) Memory for facts, source, and context: can frontal lobe dysfunction explain age-related differences? Psychol Aging 9:149-159
69. Haug H, Barmwater U, Eggers R, Fischer D, Kuhl S, Sass NL (1983) Anatomical changes in aging brain: morphometric analysis of the human prosencephalon, in Brain Aging: Neuropathology and Neuropharmacology (Cervos-Navarro J, Sarkander HI, eds), pp 1-12. Raven Press, New York
70. Ball J (1977) Neuronal loss, neurofibrillary tangles and granulovacuolar degeneration in the hippocampus with ageing and dementia. Acta Neuropathologica 37: 111-118