Research Article

MEMORY AND COGNITIVE ABILITIES IN UNIVERSITY PROFESSORS: Evidence for Successful Aging

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Abstract—*Professors from the University of California at Berkeley were administered a 90-min test battery of cognitive performance that included measures of reaction time, paired-associate learning, working memory, and prose recall Age effects among the professors were observed on tests of reaction time, paired-associate memory, and some aspects of working memory Age effects were not observed on measures of proactive interference and prose recall, though age-related declines are generally observed in standard groups of elderly individuals The findings suggest that age-related decrements in certain cognitive functions may be mitigated in intelligent, cognitively active individuals*

Genetics, experience, health, personality, and culture all contribute to changes in mental abilities across the adult life span Scientific investigations of age-related changes have been complicated by these diverse factors Indeed, many studies of cognitive aging reveal enormous variability among older adults (Albert, Duffy, & Naeser, 1987, Heron & Chown, 1967, Perlmutter, 1978, Shimamura, 1990, Zelinski, Gilewski, & Schaie, 1993) That is, some older adults exhibit only mild or moderate changes in cognitive function, whereas others exhibit significant and sometimes debilitating deficits This variability is due in part to problems in controlling for the many factors that affect performance in a group of older adults For example, cognitive performance can be affected considerably by subject factors, such as educational experience, health status, and lifestyle

In this investigation, we focused on memory and cognitive abilities in university professors There are several reasons for analyzing aging effects in this special population First, the subjects are closely matched on intellectual capacity and education Level of intellectual function can greatly influence performance on cognitive measures, and groups with varying levels of intelligence can increase within-group variability Second, the subjects share similar cultural experiences, such as work environment and socioeconomic status Controlling extraneous factors, such as intelligence and cultural experience, may make it possible to relate age-related changes to problems in specific components of cognitive function, and perhaps even to certain biological factors Finally, and most important, an analysis of individuals who are mentally active throughout the life span may provide clues to successful aging (Baltes & Baltes, 1990, Schaie, 1990, 1994) That is, professors may develop efficient use of cognitive abilities or strategies that may prevent or mitigate aging effects

University professors between the ages of 30 and 71 years were administered a battery of memory and cognitive tests The particular tests were chosen because they were known to be sensitive markers of age-related changes (e g , choice reaction time, free recall) or known to be associated with circumscribed neurological dysfunction (e g , medial temporal or frontal lobe impairment) Several hypotheses were entertained with regard to the identification of successful aging For instance, professors may generally perform well, but age-related changes may still be present That is, performance by professors may be similar to that observed in standard studies of aging but perhaps differ only in the magnitude of age-related changes Alternatively, there may be qualitative differences between patterns of performance exhibited by professors and by standard groups of elderly people Indeed, it may be that some cognitive abilities change differently or do not at all diminish during the working years in professors

METHOD AND RESULTS

Subjects

We tested 72 professors who were employed at the University of California, Berkeley Subjects were divided into three age groups 22 young professors (16 men, 6 women), who averaged 38 4 years of age (range = 30–44 years) and 22 years of education, 28 middle-aged professors (24 men, 4 women), who averaged 52 2 years of age (range = 45–59 years) and 21 years of education, and 22 senior professors (19 men, 3 women), who averaged 64 7 years of age (range = 60–71 years) and 21 years of education Professors were culled from many disciplines, including anthropology, biology, English, geology, history, music, physics, psychology, and sociology Professors were recruited by publicizing the study in *The Berkeleyan*, a newsletter for faculty and staff, by mailing requests to individual faculty, and by telephoning to request volunteers directly Each subject was paid $15 for participating in the experiment

For comparison purposes, we present data from standard groups of young and old subjects The young subjects consisted of 12 to 40 undergraduate students, depending on the test measure The entire sample of 40 young subjects averaged 19 8 years of age (range = 18–23 years) and 14 years of education The standard group of old subjects consisted of 17 individuals with a mean age of 66 5 years (range = 60–71 years) and an

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average of 16 years of education We use these groups of subjects as benchmarks for comparing the present findings from professors with findings from standard subject samples used in typical studies of cognitive aging (e g , college students vs education-matched older individuals) However, it is inappropriate to compare these subjects directly (i e , statistically) with the professors in terms of the age factor alone In particular, these two control groups differ from the professors in years of education Thus, the central focus of the present study is to delineate the age effects among the professors

General Procedure

The professors were administered a 90-min test battery These tests focused on aspects of learning and memory, as this domain of cognitive function is generally the one most affected by aging (Craik & Jennings, 1992, Kausler, 1991, Light & Burke, 1988) We also included tests of reaction time, because they too provide sensitive measures of cognitive aging (Botwinick, 1984, Hicks & Birren, 1970, Salthouse, 1991) Specific methods and results for each measure are described in the following sections

Reaction Time

Response slowing is endemic among normal elderly individuals Indeed, some researchers have viewed response slowing as the primary contributor to many, if not all, age-related declines in cognitive function (Cerella, 1985, Myerson, Ferraro, Hale, & Lima, 1992) It has been suggested that slowing provides an index of biological aging, perhaps reflecting general neuronal efficacy (Welford, 1958) Previous studies have shown that response slowing in the elderly has a central or cognitive component as opposed to a purely motor locus For example, the difference in reaction time between young and old subjects increases with stimulus complexity or task difficulty (Jordan & Rabbitt, 1977) Also, age differences appear to reflect a general slowing factor, as indicated by the fact that increases in reaction time exhibited by elderly individuals as task difficulty increases are proportional to increases exhibited by young individuals (Brinley, 1965, Cerella, 1985, Myerson et al , 1992)

In the present study, reaction time was assessed by key-press responses to visual stimuli presented with a Macintosh computer Key-press responses were obtained using a response box consisting of a center key and four additional keys (one above, one below, one to the left of, and one to the right of the center key) In the simple reaction time task, subjects were instructed to depress the center key as soon as a stimulus appeared on the screen The stimulus was either the word "go" (word condition) or a symbol representing a traffic light (symbol condition) To reduce anticipatory responses, we varied the duration between a warning cue and the target stimulus between 1,500 and 4,000 ms In the two-choice task, the word ("left" or "right") or symbol (arrow pointing left or right) indicated whether the key-press response should be to the left or right key In the four-choice task, the word or arrow indicated whether the key-press response should be up, down, left, or right Each condition included a total of 32 trials

Figure 1 shows reaction times for the simple, two-choice, and four-choice tasks Age differences were apparent between the standard young and old groups Specifically, overall slowing was observed (F[1, 59] = 99, $p <$ 001), older subjects exhibited increased reaction time with increases in choice complexity (Age × Choice interaction, F[2, 118] = 55 6, $p <$ 001), and responses to symbolic (i e , arrow) stimuli were faster than responses to word stimuli (F[1, 59] = 193, $p <$ 001) Similar age effects were observed among the three groups of professors a main effect of age (F[2, 68] = 12 4, $p <$ 01), an Age × Choice interaction (F[4, 136] = 2 4, $p <$ 05), and a main effect of stimulus type (F[1, 68] = 113, $p <$ 01) Thus, older professors exhibited typical patterns of slowing in response to verbal and symbolic stimuli

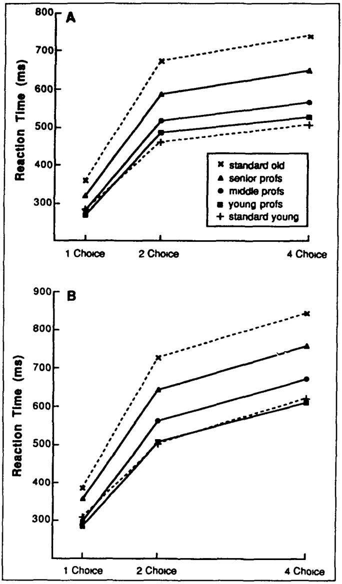

Fig 1 Reaction time on one-choice (simple), two-choice, and four-choice tests with arrow stimuli (a) and word stimuli (b) Dashed lines represent data from standard groups, solid lines represent data from professors

We performed a correlational analysis between reaction time and age of professor. Only professors were analyzed using this method because the ages of the professors were distributed evenly across the age range. There was a significant correlation between reaction time and age ($r = .53$, $p < .05$). A linear regression analysis revealed a least square regression slope of 3.9 ms/year, which is the estimated rate of response slowing among professors aged 30 to 71 years. Thus, the pattern of age-related deficits in professors was similar to that observed in standard groups of young and old individuals.

Paired-Associate Learning

Remembering arbitrary associations, such as pairing a name to a face or a phone number to a friend, places heavy demands on memory because of the inherent absence of meaningful links. Paired-associate learning paradigms have been useful in assessing this aspect of memory (for review, see Crowder, 1976; Postman & Underwood, 1973). In such paradigms, subjects are presented stimulus pairs (e.g., *table–dollar*) and later asked to remember the second item when cued with the first (e.g., *table–?*). Studies of neurological patients have demonstrated that patients with damage to the medial temporal region (e.g., hippocampus) exhibit severe impairment in paired-associate learning tests and in other tests of new learning capacity (Shimamura, 1989; Squire & Shimamura, 1986). Such findings suggest the role of the medial temporal region may be related to establishing new associative memories (Rudy & Sutherland, 1992; Squire, 1992). These findings are relevant to aging research because neuropathology—such as the presence of senile plaques—occurs prominently in the medial temporal region in aged brains. Also, atypical forms of aging, such as Alzheimer's disease, can disproportionately affect the medial temporal region and thus the learning of new associations (Meencke, Ferszt, Gertz, & Cervos-Navarro, 1983).

In the tests of paired-associate learning, face-face pairs and name-name pairs were constructed. For the face-face test, subjects were presented 6 pairs of faces (4-s exposure duration), with each pair consisting of a line drawing of a female face and a male face. Following presentation of the pairs, each of the female faces was shown again, and subjects were asked to select from a display of all 6 male faces the one that was associated with each female face. For the name-name test, subjects were presented 10 name-name pairs, each consisting of one male and one female name (e.g., "Edward & Nancy"). Following presentation of the name pairs, each of the male names was shown again, and subjects were asked to select from a display of all 10 female names the one that was associated with each male name. We developed these tests to allow a close comparison between verbal and pictoral memory and to provide a format that older subjects would find practical. Subjects were told that each face and name pair should be remembered as a male-and-female "couple." Also, a recall test for the pictoral (face) test was impractical, so we used a recognition test for both pictoral and verbal tests.

Learning was assessed across three successive study-test trials. As shown in Figure 2, age-related changes were observed in the performance of the standard young and old groups on tests of paired-associate learning for both face ($F[2, 66] = 20.4$, $p < .01$) and name ($F[2, 66] = 67.2$, $p < .01$) pairs. Age-related memory changes were also observed among the groups of professors for both the face test ($F[2, 69] = 4.18$, $p < .05$) and the name test ($F[2, 69] = 6.14$, $p < .01$). As in the analysis of reaction time, the pattern of performance by the professors was

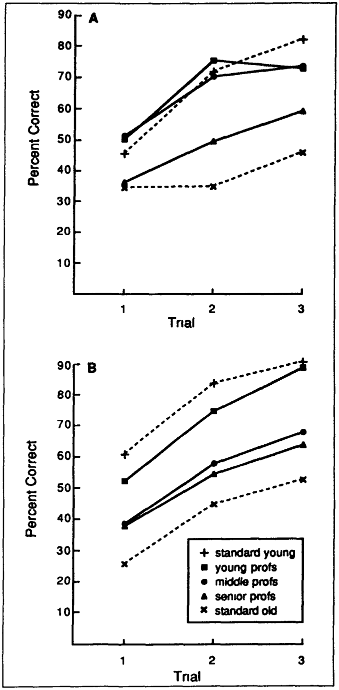

Fig. 2. Paired-associate memory across three successive study-test trials with face-face pairs (a) and name-name pairs (b). Dashed lines represent data from standard groups; solid lines represent data from professors.

similar to that observed in standard control groups of young and old adults The professors were not immune to the age effects associated with the learning of arbitrary information

An interesting pattern of performance emerged in the analysis of verbal and nonverbal memory For face-face pairs, a significant age effect was observed between middle-aged professors and senior professors ($t > 13$ 2, $p <$ 05) The young and middle-aged professors performed similarly For name-name pairs, a significant age effect occurred earlier, that is, a significant effect was observed between the young and middle-aged professors (ts > 11 9, $p <$ 05), but there was no difference between the middle-aged and senior professors These findings suggest differences in the time course of age-related changes in memory for verbal and nonverbal material and suggest the need for further analyses using middle-aged subjects

Working Memory

Working memory refers to a short-term memory process that is involved with on-line monitoring or control of information (Baddeley, 1986) Performance on tasks involving working memory is disrupted by frontal lobe lesions (Goldman-Rakic, 1987, Petrides & Milner, 1982, Shimamura, 1994) This finding is particularly relevant to studies of aging because neuronal atrophy due to the normal aging process occurs in the frontal lobes more than any other cortical regions (Haug et al , 1983, Ivy, MacLeod, Petit, & Markus, 1992)

We administered the self-ordered pointing task, a working memory test that is sensitive to frontal lobe pathology in humans (Petrides & Milner, 1982) In this test, subjects are shown repeated presentations of a computer-generated array of visual patterns (see Fig 3a) On each of 16 presentations, the patterns were arranged randomly in the array, and subjects were instructed to point to a pattern, with the restriction that they should point to a different pattern on each trial This task required subjects to monitor responses to stimuli across a block of 16 trials We increased the demand on working memory by having subjects perform the task again in a second block of trials using the same stimulus patterns In this way, we required subjects to monitor and remember responses made within a block and between blocks of trials

A study of age effects on the self-ordered pointing task (Shimamura & Jurica, 1994) showed that standard groups of older adults between the ages of 60 and 70 perform as well as young adults on the first block of trials but fail to maintain a low error rate on the second block of trials (see Fig 3b) One explanation for this finding is that older adults have problems discriminating responses made on the first block of trials from those made during the second block This finding is in accord with recent studies in which aging appears to affect the ability to inhibit or disregard irrelevant or interfering information (Hasher, Stoltzfus, Zacks, & Rypma, 1991) Such disruptions can be viewed as a consequence of increased *proactive interference*—that is, a decrement in memory performance as a result of interference from prior experiences Problems associated with increased proactive interference or problems in inhibiting extraneous information are often observed in patients with frontal lobe lesions (Shimamura, Jurica, Mangels, Gershberg, & Knight, 1995) and in older adults (Hartman & Hasher, 1991)

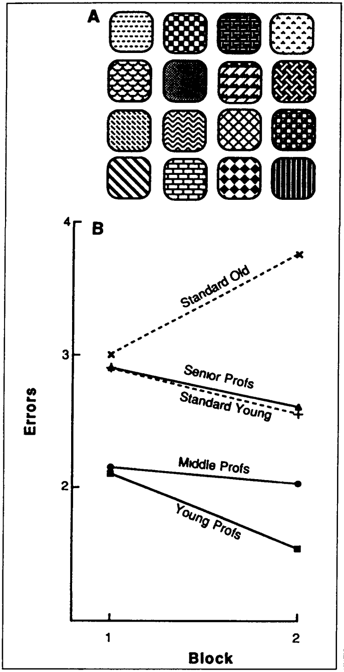

Fig 3 Stimulus array (a) for the self-ordered pointing task and mean error scores (b) on that task for professors and standard groups (data from Shimamura & Jurica, 1994)

The professors performed well on the self-ordered pointing task Age differences were observed among the three groups of professors, $F(2, 66) = 3$ 29, $p <$ 05 Yet there was an important qualitative difference between the pattern of the age effects in the professors and in the standard old group None of the groups of professors exhibited an increase in errors across test blocks It may be that professors were better able to devise and use efficient strategies to prevent or reduce the influence of proactive interference Nonetheless, the finding of an age effect among the groups of professors suggests that some abilities tapped by this test are age-dependent

Prose Recall

A prominent feature of intellectual activity is the acquisition and organization of conceptual knowledge Tests of prose recall assess subjects' ability to incorporate and retain new facts within an existing knowledge base Significant age decrements are typically observed on tests of prose recall, although decrements can be mitigated by high verbal ability (Hartley, 1989, Meyer & Rice, 1981) In the present study, subjects heard three prose passages—a standard prose passage used in clinical assessment of memory, a prose passage involving scientific information, and a prose passage involving historical-anthropological information

Each prose passage was tape-recorded and presented auditorily to the subjects One passage came from the Wechsler Memory Scale-Revised (WMS-R, Wechsler, 1987) and consisted of a fictional story about a woman, Anna Thompson, who was robbed In this standard test, the text is divided into 25 conceptual phrases or segments, and performance is scored as the percentage of segments recalled Two other passages were obtained and segmented One involved scientific information about the elements that make up the earth's atmosphere The other passage involved anthropological-historical information about the tribal cultures in the Mississippian period Recall performance for these two passages was based on memory for 25 conceptual phrases per passage and scored in the same manner as the text used in the WMS-R

Prose recall was assessed immediately after presentation of the passage Age-related changes were observed in the comparisons between the standard young and old groups, $F(2, 67) = 16\ 6$, $p < 01$ In contrast, professors of all ages performed well on tests of prose recall (see Fig 4) Indeed, on the three different prose passages, senior professors recalled as many details as young professors, $F(2, 69) = 1\ 6$, $p > 2$

DISCUSSION

This investigation of cognitive and memory performance in professors highlighted several factors associated with aging On two tests—tests of reaction time and paired-associate learning—age-related decrements observed in professors were similar to those observed in standard studies of aging Thus, professors were not completely immune to age-related cognitive changes In particular, slowing appeared to be a strong predictor of age and perhaps the best predictor of biological factors associated with the aging process Findings of age-related deficits in paired-associate learning suggest that intelligence and mental activity during adulthood cannot prevent problems in memory for arbitrary associations, such as associating names to faces or phone numbers to colleagues Arbitrary associations may be particularly affected because such associations do not significantly draw upon conceptual knowledge or reasoning

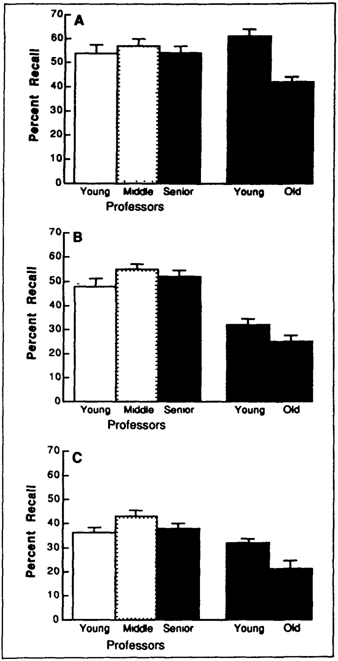

Fig 4 Recall performance for a prose passage used in the Wechsler Memory Scale-Revised (a), a prose passage concerning scientific facts about the earth's atmosphere (b), and a prose passage concerning anthropological-historical information about the Mississippian period Bars on the left represent data from professors, and bars on the right represent data from standard groups Error bars refer to standard errors of the mean

In the present study, age effects in two domains of cognitive function appeared to be different from the effects observed in standard studies of aging In the self-ordered pointing test, proactive interference across blocks of trials, which was observed in a previous study of aging (Shimamura & Jurica, 1994), was not apparent in the performance of professors Although overall errors in this task did increase with age among the professors, none of the age groups exhibited the disproportionate increase in errors from the first to the second block of trials Thus, an aspect of this test of working memory was immune to age decrements Finally, prose recall performance was equivalent for senior, middle-aged, and young professors Interestingly, these two memory measures—proactive interference and prose recall—are typically very sensitive measures of age-related decline

The findings from this special population offer some unique insights into the spectrum of aging patterns observed in adulthood In particular, these findings provide information concerning exceptional or boundary conditions of performance Age-related effects have been studied in other special populations, including pilots, skilled technicians, and business executives (for review, see Salthouse, 1991) Indeed, Sward (1945) assessed young (age 25–35 years) and senior (age 60–79 years) professors on a variety of mental abilities, including tests of arithmetic, verbal ability, symbol substitution, and problem solving He observed age decrements on six of the eight test measures The most prominent declines occurred on the two tests with time limitations, suggesting that the deficits may be related to cognitive slowing In addition, many of these tests involved arbitrary association of novel symbols to digits or words (e g , symbol-digit substitution task) In the present study, professors' age-related deficits on tests of reaction time and arbitrary paired-associate learning are consistent with Sward's findings Sward did not find aging effects on two tests—identifying synonyms and antonyms and identifying word meanings

There are several prominent differences between the present study and the one by Sward (1945) First, we assessed only actively employed professors, whereas the previous study included emeriti professors Second, we assessed primarily memory abilities rather than intellectual abilities Third, we did not subject the professors to arduous, mentally taxing problems, whereas in the previous study, 11 older and 4 younger professors complained of being tired during a session Nevertheless, Sward's conclusions closely match ours Specifically, Sward viewed the primary age effect as one of cognitive slowing and was more impressed by individual differences than by the effects of aging among professors

In the present study, there is an interesting commonality between the test measures that showed no or little age effect Specifically, the mitigation of proactive interference and prose recall require planning, organization, and the manipulation of information in memory They also draw considerably upon contextual information—information embedded within a spatiotemporal framework or within a knowledge-based framework These two factors are related because access to information within a contextual framework requires efficient planning, organization, and retrieval strategies Perhaps professors are facile in their use of such strategies to access knowledge as a result of daily activities that require the integration of new knowledge into existing knowledge representations Their facility with these strategies may compensate for decrements in the mechanics of cognitive function, such as decrements caused by cognitive slowing

In standard groups of elderly individuals, tests that tap higher order abilities, such as planning, organization, and problem solving, are generally the most affected Thus, the preservation of performance on these tests in professors stands in marked contrast to typical findings from studies of aging Neuropsychological investigations have demonstrated that the deployment of higher order strategies is particularly affected by frontal lobe lesions (for review, see Moscovitch, 1992, Shimamura, 1994, Stuss, Eskes, & Foster, 1994) Generally, patients with damage to the dorsolateral prefrontal cortex exhibit impairment on tests of problem solving, planning, and working memory (Baddeley, 1986, Milner, Petrides, & Smith, 1985, Stuss et al , 1994) Moreover, they are more susceptible to proactive interference (Shimamura et al , 1995), exhibit impairment on tests of free recall (Gershberg & Shimamura, in press, Jetter, Poser, Freeman, & Markowitsch, 1986), and do not appear to organize memory efficiently (Eslinger & Grattan, 1994, Gershberg & Shimamura, in press) As mentioned, these neuropsychological findings are important for the study of normal aging because neuronal atrophy due to the normal aging process occurs most prominently in the frontal lobes (Haug et al , 1983)

This investigation suggests two possibilities in terms of the biological foundation underlying aging and cognitive function One possibility is that mental activity reduces the changes that typically occur as a result of aging That is, mental activity may protect cognitive functions from typical age-related changes Of course, mental activity cannot be the only factor, genetic factors and other early influences must also contribute significantly to the status of mental and neural function in later life Another possibility is that age-related changes occur to the same extent in all individuals, including professors, and that professors' preserved performance on behavioral measures is the result of an enhanced ability to compensate for decrements For example, efficient use of memory strategies developed during adulthood may compensate for biological aging effects, such as generalized slowing The present findings suggest a compensatory role of mental activity because clear age-related declines were observed in the basic mechanics of cognitive function (e g , reaction time) However, more direct analyses, perhaps involving noninvasive neuroimaging techniques (e g , magnetic resonance imaging), may provide important clues to the ways in which individuals adapt successfully to the aging process

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