

The Relationship Between Executive Functioning
And Memory Performance In Healthy Older Adults

by

Angela Kay Troyer
M.A., University of Victoria, 1990
B.A., Bethel College, 1988

A Dissertation Submitted in Partial Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY

In the Department of Psychology

We accept this thesis as conforming to the required standard

Roger E. Graves, Ph.D., Supervisor (Department of Psychology)

Pam Duncan, Ph.D., Departmental Member (Department of Psychology)

Otfried Spreen, Ph.D., Departmental Member (Department of Psychology)

Donald W. Knowles, Ph.D., Outside Member (Department of Psychological
Foundations in Education)

Catherine Mateer, Ph.D., External Examiner (Department of Neurological
Surgery, University of Washington)

© Angela Kay Troyer, 1993

University of Victoria

All rights reserved. Thesis may not be reproduced in whole or in part, by
photocopying or other means, without the permission of the author.

Supervisor: Dr. Roger Graves

Abstract

The typical pattern of age-associated differences in neuropsychological functioning primarily involves poorer executive and recent-memory abilities in older than younger adults. Among healthy older adults, a substantial proportion of the age-related differences in memory performance may actually be due to age differences in executive functioning, because executive skills such as organization and strategy formation are thought to be necessary for effective memory recall, and these skills are related to age. Furthermore, young individuals with executive dysfunction due to frontal-lobe damage exhibit impairments on some memory tests, and the specific pattern of difficulties demonstrated in this population bears a striking resemblance to that of healthy older adults.

In the present study, the hypothesis that age-related differences in executive functioning contribute to age-related differences in performance on recent-memory tests was examined. Tests of memory (i.e., the Rey-Osterrieth Complex Figure and the California Verbal Learning Test) and tests of executive functioning (i.e., the Visual-Verbal Test, the Hooper Visual Organization Test, and the Stroop task) were administered to a group of 51 healthy adults age 60 to 91 years. As additional measures of executive abilities, the organizational strategies utilized on the two memory tasks were evaluated (i.e., "good continuation" and "symmetry" on the Complex Figure and "semantic clustering" on the California Verbal Learning Test). These scores were subsequently tested with

regression analyses within a mediational model. Consistent with this model, the analyses indicated that, when considered alone, age was a significant predictor of recent-memory recall ($p < .001$); however, age was not a significant predictor of recall when the effect of executive functioning was partialled out of the equation ($p = .37$). Furthermore, the indirect effect of age on recent-memory recall via executive functioning was statistically significant ($p < .005$). Executive functioning uniquely accounted for 36% of the variance in memory recall. A major proportion of the age-related differences in recent-memory recall, therefore, appears to be due to the demands for executive skills for optimal performance on these memory tests.

Examiners:

Roger E. Graves, Ph.D., Supervisor (Department of Psychology)

Pam Duncan, Ph.D., Departmental Member (Department of Psychology)

Otfried Spreen, Ph.D., Departmental Member (Department of Psychology)

Donald W. Knowles, Ph.D., Outside Member (Department of Psychological Foundations in Education)

Catherine Mateer, Ph.D., External Examiner (Department of Neurological Surgery, University of Washington)

Table of Contents

| | |
|--|------|
| Abstract | ii |
| Table of Contents | iv |
| List of Tables | vi |
| List of Figures | vii |
| Acknowledgements | viii |
| Dedication | ix |
| Introduction | 1 |
| Definitions and Methodological Issues | 2 |
| Physical Changes in the Aging Brain | 3 |
| Neuropsychological Changes in Healthy Aging | 7 |
| The Effect of Executive Difficulties on Memory | 14 |
| Memory in Frontal-Lobe Injury and In Healthy Aging | 17 |
| Overview of Present Research | 29 |
| Methods | 32 |
| Subjects | 32 |
| Materials | 35 |
| Procedures | 42 |
| Plan of Analysis | 43 |
| Results | 49 |
| General Test Performance | 49 |

| | |
|--|-----------|
| Age Differences in Demographics and General | |
| Functioning | 51 |
| Mediational Model | 51 |
| Unique Contribution of EF to Memory | 54 |
| Discussion | 55 |
| Implications | 56 |
| Contradictory Studies | 58 |
| Age and Isolate Responses | 59 |
| Representativeness of the Sample | 60 |
| Directions for Future Research | 61 |
| References | 64 |
| Appendix | 77 |

List of Tables

| | | |
|-----------------|--|-----------|
| Table 1. | Demographic Information | 34 |
| Table 2. | Mean Test Performance on Measures of General Functioning, Memory, and Executive Ability | 50 |

List of Figures

| | | |
|------------------|---|-----------|
| Figure 1. | Models used to test mediation | 45 |
| Figure 2. | Models used to test mediation, with data | 53 |

Acknowledgements

I would like to thank the members of my supervisory committee for their input into the dissertation: Roger Graves for his helpful comments and advice; Pam Duncan for her suggestions and wonderful support; Otfried Spreen, Don Knowles, and Catherine Mateer for their thoughtful comments.

I gratefully acknowledge the helpful contributions of Munro Cullum, who sparked my original interest in studying the neuropsychological aspects of aging. Via consultative discourse, Dr. Cullum helped me to choose among my original ideas for this project, provided advice about selecting appropriate age groups in research with older adults, encouraged me to examine the existing literature to determine how various patient populations perform on the proposed tests, and suggested the use of qualitative measures of performance. I am also grateful to Kathy Montgomery for her suggestions and for the use of her testing materials. In addition, I would like to acknowledge the helpful advice of my fellow graduate students, including Jennifer Maggs, Don Hine, and Dave Almeida.

I am very grateful to Shawn O'Connor for his generous advice and constant support. I have greatly appreciated the encouragement, support, and warmth of my family, including Mom and Dad, Cyndie, Rich, Bill, Jake, and Katie.

This work was funded in part by a University of Victoria Fellowship granted to myself. A grant to Dr. Graves from the Natural Science and Engineering Research Council of Canada covered miscellaneous expenses and provided a computer for my use.

Dedication

**This dissertation is dedicated with warmth and affection
to my grandparents:**

John and Gertrude Powell

Frieda and Ora Troyer

Introduction

Interest in studying the neuropsychological functioning of older adults has increased considerably in recent years. This is likely due in part to prolonged life expectancies and a consequent increase in the prevalence of older people in our society (Statistics Canada, 1990). For neuropsychologists, this trend signifies a growing need for assessment of diseases and disorders that increase in prevalence with age, such as dementia and stroke. As a result, there is also a growing need to study the changes that occur in healthy aging so that these can be distinguished from the effects of diseases common in this population (discussed in Albert & Moss, 1988). In order to fully understand neuropsychological disorders in geriatric populations, thus, it is necessary first to understand "normal" or "healthy" aging.

In the following section of this thesis, definitions and methodological considerations relevant to the study of healthy aging are discussed. Next, the physical brain differences between younger and older adults are briefly described, and these are related to the typical pattern of age-associated differences in neuropsychological functioning, with an emphasis on executive skills and memory. Finally, evidence suggesting that age-related differences in executive functioning may contribute to age-related differences in performance on memory tests is discussed, including the apparent similarities in the memory performance of young frontal-lobe-damaged adults and healthy older adults.

Definitions and Methodological Issues

In the field of the psychology of aging, a number of issues, including definitions of terms and methodological considerations, are crucial in determining the outcome and applicability of any particular study. It can be helpful, therefore, to establish a clear understanding of what is meant by "aging", who is considered to be "old" or "elderly" in our society, and who the "normal" older adults are.

Aging, first of all, has been defined as "the regular changes that occur in mature genetically representative individuals living under representative environmental conditions as they advance in chronological age" (Birren & Renner, 1977, p. 4). This definition emphasizes the changes that occur over time, and allows for age-related improvements in functioning as well as the more often emphasized age-related deteriorations. Indeed, aging involves both positive changes (e.g., increased information storage) and negative changes in functioning (e.g., decreased memory and learning capabilities).

The point at which an individual is considered to be "old" or "elderly" in our society has been somewhat arbitrarily set at 65 years. The necessity of extending this cutoff, however, is becoming increasingly apparent as more and more people reach older ages without significant changes in their functional capacities. Indeed, noticeable age differences often do not occur until after the age of 75 or 80 (Benton, Eslinger, & Damasio, 1981; Katzman & Terry, 1983). A more recent classification system has been developed to take this into

consideration, and consists of classifying adults between 65 and 75 years as "young-old" and those over 75 years as "old-old" (Katzman & Terry, 1983).

A final term, "normal" aging, has been conceptualized in a number of ways (e.g., Drachman, 1986; Drachman & Long, 1984; Van Gorp & Mahler, 1990). One definition of normal older adults includes all individuals over the age of 65 who perform within two standard deviations of the mean of their age group on any given test. This definition encompasses a heterogeneous group of people, however, because a majority of older adults have at least one major disability (Statistics Canada, 1990). Another conceptualization of normal older adults excludes individuals with known systemic or neurological disorders and defines "normal" as disease-free. This is the type of group that would be used in studies attempting to distinguish functional declines due to disease and those due to aging alone. The performance of these individuals represents the best possible functioning for their age group, although it is not representative of their peers, most of whom will have significant diseases or disorders. Obviously, the definition used in any particular study will greatly affect the results obtained (Hochanadel & Kaplan, 1984). That is, the use of a comprehensive group will maximize age differences, whereas the use of healthy subjects will minimize these differences.

Physical Changes in the Aging Brain

Regardless of the type of healthy older subjects examined, it is apparent that the brain undergoes specific physical changes with advancing age. This has

been demonstrated in studies of the gross morphology, histology, neuropathology, electrical activity, and cerebral metabolism of the brain (reviewed in Bondareff, 1985; Pinn, 1988; Van Gorp & Mahler, 1990). Many of these changes tend to be region-specific rather than global, affecting primarily the frontal and temporal brain areas.

Gross morphology and histology. Research has consistently noted overall age-related differences in the gross morphology of the brain. Significantly lower brain weights (Creasey & Rapoport, 1985; Drachman & Long, 1984; Terry, DeTeresa, & Hansen, 1987) and brain volumes (Zatz, Jernigan & Ahumada, 1982) have been demonstrated in older adults. It is apparent that these age-associated differences are first evident in young adulthood and then accelerate during the fifth, sixth, seventh, and eighth decades (Albert & Stafford, 1988).

The most likely sources of age-related differences in gross morphology are the histological processes of neuron atrophy and neuron loss. There is considerable evidence that neurons decrease in size with age; this atrophy occurs globally but is most pronounced in the frontal and temporal regions of the brain (Bondareff, 1985; Schiebel, 1981; Terry et al., 1987). Neurons also appear to decrease in number with advancing age (Bondareff, 1985; Creasey & Rapoport, 1985), although it has been argued that this apparent cell loss is actually an artifact of cell atrophy (Terry et al., 1987). In those studies reporting neuron loss, these changes are specific to certain brain areas, occurring primarily in the frontal lobes and secondarily in the temporal lobes; no substantial losses have been noted

in the parietal and occipital lobes (Bondareff, 1985; Creasey & Rapoport, 1985; Katzman & Terry, 1983). This pattern of regional cell loss and atrophy suggests the presence of selective histological changes with age involving the frontal and temporal lobes.

Neuropathological deposits and lesions. Some microscopic deposits and lesions that increase in prevalence with age are unevenly distributed within the brain. Senile plaques and neurofibrillary tangles, for example, are found in the brains of healthy older people and are usually limited to the hippocampal areas of the temporal lobe (Bondareff, 1985; Creasey & Rapoport, 1985; Katzman & Terry, 1983). In addition, asymptomatic ischemic lesions have been found in the white matter of the brain in some older adults and are most prominent in the tissue surrounding the frontal horns of the lateral ventricles (Gerard & Weisberg, 1986). Other types of deposits and lesions, on the other hand, are distributed more evenly in the brain tissue (e.g., lipofuscin pigments and granulovacuolar degeneration vesicles; Bondareff, 1985; Van Gorp & Mahler, 1990).

Electrical activity. Age-associated changes in the electrical activity of the brain have been well documented in studies of electroencephalography (EEG) and evoked potentials (EP). With age, there are global changes in EEG activity (Duffy, Albert, McAnulty, & Garvey, 1984; Duffy & McAnulty, 1988; Printz, Dustman, & Emmerson, 1990). In addition, there are region-specific changes in the EEG that predominate in the temporal and frontal regions of the brain (Creasey & Rapoport, 1985; Duffy et al., 1984; Printz et al., 1990).

The EP technique is used to record electrical brain responses to environmental stimuli. In general, EP latencies increase with age, reflecting slowed conduction times (Printz et al., 1990). Similar to the EEG findings, age-related changes in EP appear to be prominent in specific brain regions; the most severe slowing is found in the frontal areas of the brain (Ford & Pfefferbaum, 1980; Michalewski et al., 1980; Smith, Thompson, & Michalewski, 1980). Overall, studies using EEG and EP support the idea that changes in electrical activity are selective, occurring predominately in the frontal and temporal brain regions.

Cerebral metabolism. Neuronal activity in the brain is measured by examining blood flow, glucose metabolism, and oxygen metabolism. Overall, studies examining age-related differences in these measures are conflicting. Whereas some studies show lower levels of blood flow and metabolism with advancing age (Katzman & Terry, 1983; Kuhl, Metter, Riege, & Hawkins, 1984; Warren, Butler, Katholi, & Halsey, 1985), others do not (Duzara et al., 1984; Printz et al., 1990). In those studies that do demonstrate age-related differences, the frontal regions of the brain are the most severely affected (Kuhl et al., 1984; Warren et al., 1985).

Overall, therefore, evidence from a wide variety of physiological studies converges to suggest that cortical aging is a selective process. The areas of the brain that appear to undergo the most pronounced changes are the frontal and temporal lobes.

Neuropsychological Changes in Healthy Aging

Measures of physiological brain functioning, such as those previously discussed, have been found to correlate highly with measures of neuropsychological functioning including intelligence, memory, naming, and abstraction (Katzman & Terry, 1983; Rinn, 1988). As might be predicted from the pattern of localized age-related changes in the brain, age differences in neuropsychological functioning are specific rather than generalized (reviewed in Albert, 1988; Albert & Kaplan, 1980; Hochanadel & Kaplan, 1984; Van Gorp & Mahler, 1990). It is apparent that there are a variety of age-associated differences in neuropsychological functioning among healthy older adults, and the most profound of these are mediated by the frontal lobes (e.g., the executive functions) and the medial temporal lobes (e.g., memory).

Intelligence and language. In longitudinal studies, intellectual abilities begin to decline between the ages of 60 and 80 years (Schaie, 1990). Spatial intellectual skills (i.e., organization and interpretation of nonverbal, visual information) tend to decline somewhat earlier and more drastically than verbal intellectual skills (i.e., verbal reasoning and comprehension). It should be noted, however, that although group data indicate that these specific types of functioning decline with age, there is considerable individual variation and the performance of many individual subjects does not change significantly (Schaie, 1990). This individual variation appears to be related to demographic, health, situational, and even personality variables (Schaie, 1990).

There appear to be few age-related differences in language abilities (reviewed in Obler & Albert, 1985). Comprehension, syntax, and vocabulary do not tend to differ among younger and older adults. The ability to produce the names of familiar objects, on the other hand, is negatively related to age.

Attention. Some forms of attention demonstrate age-related differences whereas others do not. Simple attention abilities, as measured by the Digit Span subtest of the Wechsler Adult Intelligence Scale - Revised (WAIS-R), are not related to age in adults (Albert, 1988; Koss, Haxby, DeCarli, Schapiro, Friedland, & Rapoport, 1991). This task simply requires the subject to repeat increasingly larger strings of orally-presented digits. More complex forms of attention, on the other hand, such as divided attention and sustained attention, do show some age-associated differences which favor younger subjects (McDowd & Birren, 1990). These latter abilities involve more effortful processing, decision-making skills, and vigilance.

Executive functioning. Executive functioning involves a wide range of problem-solving abilities, including mental organization, planning, abstraction, fluency, hypothesis generation, behavioral initiation, cognitive flexibility, and impulse inhibition. These abilities are thought to be necessary for successfully engaging in purposive and independent behaviors (Lezak, 1983). More pronounced difficulties in executive functioning among older than younger adults have been widely documented (e.g., Albert, Wolfe, & Lafleche, 1990; Axelrod & Henry, 1992; Whelihan & Leshner, 1985). As reviewed below, the most well-

established of these age differences are concept formation/abstraction, cognitive flexibility, and inhibition of a dominant response. Evidence for age-related differences in verbal fluency, on the other hand, is inconsistent.

A wide variety of tests have been used to measure age-associated differences in abstraction and concept formation. Difficulties in abstract thinking among older adults have been demonstrated on the Similarities subtest of the WAIS-R, in which subjects are asked to describe how pairs of words are alike (Axelrod & Henry, 1992; Whelihan & Leshner, 1985). Difficulties with abstract thinking are also apparent on tests requiring the interpretation of proverbs (Albert et al., 1990; Albert, Duffy, & Naeser, 1987). Similarly, age differences in concept formation have been suggested by overall performance on tests requiring the subject to discover the relationships among a number of visual stimuli, including the Category test (Mack & Carlson, 1978) and the Visual-Verbal Test (Albert et al., 1990). The Wisconsin Card Sorting test is a common measure of concept formation and requires the subject to sort stimuli based on criteria that change without warning. Significant age differences have been demonstrated on the "categories" variable of this test, indicating difficulties identifying appropriate sorting criteria (Boone, Miller, Lesser, Hill, & D'Elia, 1990; Haaland, Vranes, Goodwin, & Garry, 1987; Parkin & Walter, 1991); however, one study did not demonstrate a relationship between this variable and age (Axelrod & Henry, 1992). Overall, age-related differences in abstraction and concept formation favoring younger adults have been demonstrated with a variety of clinical tests.

Age-associated differences in cognitive flexibility have also been noted. For example, older subjects have more marked difficulties producing more than one answer on the Visual-Verbal Test, indicating problems in switching mental sets (Albert et al., 1987; Albert et al., 1990). Similarly, on the Wisconsin Card Sorting Test, older adults tend to make a greater number of perseverations than younger adults, reflecting less flexibility in the generation of possible sorting principles (Axelrod & Henry, 1992; Parkin & Walter, 1991).

The ability to inhibit a dominant response also becomes more difficult with advancing age, as measured by performance on the Stroop (1935) task. On this task, a series of color words are printed in conflicting colors (e.g., "red" is printed in blue ink), and subjects are requested to name the color of the ink in which the words are printed. Thus, subjects are asked to inhibit an overlearned response (i.e., reading) in favor of an uncommon response (i.e., color naming).

Performance on this task is negatively related to age (Boone et al., 1990; Whelihan & Leshner, 1985), indicating that older subjects have more difficulties inhibiting dominant responses on demanding tasks than younger subjects do.

In contrast to other studies of executive functioning, those examining age-related differences in verbal fluency have yielded contradictory results. Fluency is measured by asking the subject to produce as many words as possible that begin with a specified letter or belong to a given category within a time limit.

Normative studies of a letter fluency test: the FAS test, show small but consistent decrements in word production with advancing age (Benton & Hamsher, 1977;

Spreeen & Strauss, 1991), and several studies have demonstrated significant age differences on this test (Benton et al., 1981; Parkin & Walter, 1991; Veroff, 1980). Similarly, there is some evidence of age differences in category fluency which favor younger subjects (Kozora & Cullum, 1993). A large number of studies, on the other hand, do not show a statistically significant relationship between age and letter fluency (Axelrod & Henry, 1992; Bolla, Lindgren, Bonaccorsy, & Bleeker, 1990; Kozora & Cullum, 1993; Mittenberg, Seidenberg, O'Leary, & DiGiulio, 1989) or between age and category fluency (Drachman & Leavitt, 1972; Whelihan & Leshner, 1985).

Overall, there appears to be a sizable amount of evidence indicating age-related differences in executive functioning, although there are some contradictory findings. The reasons for these inconsistencies in the literature are unclear. There are several factors, however, that may provide some explanation. First, there are relatively few studies examining age-related differences in executive functioning, and replications of the existing studies are uncommon. Second, a number of these studies have significant statistical weaknesses that preclude the possibility of drawing firm conclusions (e.g., failure to control the experiment-wise Type I error rate from multiple *t* tests, thereby increasing the probability of incorrectly concluding that group differences exist, in Whelihan & Leshner, 1985). Finally, studies typically use subjects who vary in age, level of education, and health status, each of which may confound the results obtained. As more studies examining age effects on executive functioning are published in the literature, the

scope and magnitude of these effects should become more apparent. For the present, however, there appears to be sufficient evidence to conclude tentatively that the performance of older adults on tests of executive functioning is poorer than that of younger adults.

Memory. Another age-associated difference in cognitive functioning is that of memory. This age difference does not appear to be pervasive; rather, only some forms of memory demonstrate progressive age differences (reviewed in Albert, 1988; Craik, 1977; Poon, 1985). No age-related differences are exhibited in sensory memory (i.e., the initial registration of new information), immediate memory (i.e., memory for information over a few seconds), or remote memory (i.e., recall of information learned many years previously). Recent-memory performance, on the other hand, is considerably poorer among older than younger adults. This type of memory refers to new learning and recall from a permanent store with an apparently unlimited capacity. The time span involved in recent memory is between immediate and remote memory; the typical assessment interval is minutes to days.

Recent memory for both verbal and visual material shows substantial age differences. Poorer performance among older adults on tests of memory for word lists have been noted on the California Verbal Learning Test (Delis, Kramer, Kaplan, & Ober, 1987) and the Rey Auditory Verbal Learning Test (Geffen, Moar, O'Hanlon, Clark, & Geffen, 1990; Ivnik, Malec, Tangalos, Petersen, Kokmen, & Kurland, 1990; Mitrushina & Satz, 1989). Other age differences in

verbal memory have been noted on tests of paragraph recall (the Wechsler Memory Scale Logical Memory subtest; Benton et al., 1981; Cullum, Butters, Troster, & Salmon, 1990) and on tests of memory for paired word associates (Benton et al., 1981; Craik, Byrd, & Swanson, 1987). Age-related differences in memory for visual designs have been documented on the Rey-Osterrieth Complex Figure Test (Bennett-Levy, 1984; Berry, Allen, & Schmitt, 1991; King, 1981; Ska & Nespoulous, 1988) and the Wechsler Memory Scale Visual Reproduction subtest (Benton et al., 1981; Cullum et al., 1990; Koss et al., 1991). These latter tests require the subject to view a visual design and later draw the design from memory. Age differences in memory performance favoring younger subjects, therefore, are evident on a wide variety of clinical memory tests, including those measuring retention of both verbal and visual material.

The age-related difference in recent-memory performance appears to be a result of poor encoding and/or retrieval of material to be remembered by older adults rather than poor memory storage per se (Mitrushina & Satz, 1989; Smith, 1980). Evidence for this comes from studies of recognition versus recall. That is, recognition and cued recall of information show smaller age-related differences than does free recall, implicating a failure of retrieval processes as opposed to inadequate information storage (Smith, 1980). In addition, many studies have demonstrated that forgetting rates are equivalent for young and older subjects, further supporting the idea that age-related memory differences are not due to

faster deterioration of information from memory in older adults (e.g., Mitrushina & Satz, 1989; Smith, 1980).

In summary, previous research has documented age-associated differences (favoring younger subjects) in intellectual functioning, complex attention skills, executive functioning, and recent memory abilities. The most profound of these appear to involve executive and memory skills. No significant age differences, on the other hand, are evident in language, simple attention skills, immediate memory, remote memory, and information storage.

The Effect of Executive Difficulties on Memory

Because the frontal-lobe-mediated executive functions involve such a wide variety of abilities, it is not difficult to imagine that poor executive functioning could potentially result in disruption of other cognitive abilities, such as memory. It is generally agreed, however, that frontal-lobe dysfunction is not associated with a true amnesia; rather, it is thought to interfere with a number of cognitive functions necessary for successfully engaging in the acquisition and retrieval of information (Luria, 1973; Stuss & Benson, 1986). As subsequently described, these necessary functions include organization and elaboration of material at encoding, strategic retrieval of information, and the ability to overcome the effects of interference.

According to information-processing theories, organization and elaboration of material is required for long-term-memory acquisition (e.g., Craik & Lockhart,

1972). It is clear that most young-adult subjects spontaneously impose structure on unorganized material to be remembered and that this tendency to structure information is associated with better memory performance. Tulving (1962), for example, found that university students imposed a sequential structure on a list of unrelated words they were required to remember and that this organization was positively correlated with recall. On a memory test for a complex visual design (i.e., the Rey-Osterrieth Complex Figure), several researchers have demonstrated that perceptual organization at input (as measured by the copying strategy used) was strongly related to subsequent recall of the figure (Bennett-Levy, 1984; Ska & Nespoulous, 1988). The ability to impose organization and structure on material at the time of encoding, therefore, is related to later recall of that material.

Another executive skill required for free recall of information is the ability to formulate strategies and engage in organizational processes at retrieval (e.g., Moscovitch, 1989). Strategic retrieval involves mentally reconstructing the spatial and temporal contexts in which a particular piece of information or event was encountered in order to aid in the recall of that information. It has been proposed that memory impairments in subjects with frontal-lobe dysfunction are due in part to an impaired ability to engage in this type of strategic processing (e.g., Moscovitch, 1989). Thus, it would appear that the executive functions of strategy formation and organization are involved in information recall.

Adequate memory performance also requires the ability to overcome effects of interference (Stuss, Kaplan, Benson, Weir, Chiulli, & Sarazin, 1982).

That is, in order to recall a particular piece of information, it must be distinguished from other interfering material in memory. When interference is not overcome, the subject may perseverate on previously-encountered material and be unable to retrieve the appropriate information from memory. A number of executive functions, therefore, including organization, elaboration, strategic retrieval, and overcoming interference would appear to be involved in performance on many memory tasks.

In the clinical assessment of memory difficulties, it is important to distinguish these types of executive difficulties from true memory impairments so that one may obtain an accurate picture of the client's strengths and weaknesses.

Goldberg and Bilder (1986) stated that

It is often assumed that deficient performance on a memory task necessarily implies impaired storage and/or retrieval. In fact, it is entirely possible that deficient encoding strategies or executive control contribute to poor performances as much as or more than faulty storage and/or retrieval. The common failure to recognize such contributions to poor performance on a task designed to measure memory may lead to an erroneous formulation of the nature of the deficit (p. 55).

It is apparent, therefore, that executive difficulties can interfere with adequate performance on tests that are thought to measure memory. Apart from the theoretical interests that this idea may generate, it is also clear that there are important clinical implications of this information.

Memory in Frontal-Lobe Injury and in Healthy Aging

Sufficient evidence has accumulated to suggest that executive functioning is mediated by the frontal lobes of the brain. Executive dysfunction, for example, is apparent primarily in people who have sustained lesions of the frontal lobes (reviewed in Damasio, 1985; Milner & Petrides, 1984; Stuss & Benson, 1986). Some of the most common etiologies of frontal-lobe lesions are traumatic head injury, tumors, and cerebrovascular accidents (e.g., ruptured aneurysm of the anterior communicating artery). Also, Korsakoff's amnesia is thought to involve frontal-lobe dysfunction in addition to diencephalic damage (Moscovitch, 1982; Squire, 1982), and consequently these patients are sometimes used in studies of frontal-lobe damage.

Consistent with the view that executive functioning is necessary for adequate performance on many memory tasks, people with frontal lobe lesions of various etiologies perform quite poorly on some memory tests (Mayes, 1986; Milner & Petrides, 1984; Moscovitch, 1989). Below-average performance by this population has been demonstrated on free recall of word lists (Jetter, Poser, Freeman, & Markowitsch, 1986), paragraphs (Novoa & Ardila, 1987), paired word associates (Benton, 1968), paired nonverbal associates (Petrides, 1985, 1990), facial affect (Prigatano & Pribram, 1982), and visual designs (Bigler, 1988; Villki, 1989). It should be noted, however, that such memory impairments are not found in all studies, and the precise effect of frontal lobe lesions on memory performance remains somewhat elusive (see Stuss & Benson, 1986).

It would appear, then, that frontal-lobe dysfunction contributes directly or indirectly to memory deficits on some tasks. Consistent with this view, a recent study demonstrated that, among patients with known frontal dysfunction due to Parkinson's Disease, learning and memory were not significantly impaired after the effects of executive dysfunction were statistically removed (Bondi, Kaszniak, Bayles, & Vance, 1993). Part of the demonstrated memory impairment in this population, therefore, may be due to the concurrent deficits in executive functioning.

Among healthy older adults, age-related differences in both executive functioning and memory have been well documented, as previously discussed. As with frontal-lobe-impaired subjects, it is possible that part of the age-related difficulty in memory-test performance may be attributable to difficulties in executive functioning. Evidence to support this possibility can be obtained by examining the qualitative characteristics of memory performance among healthy older adults; features reflecting age-related difficulties in executive functioning such as poor organization of material and perseveration appear on some memory tasks. Additional evidence is obtained by comparing patterns of memory performance among people with known frontal-lobe damage and healthy older adults. As reviewed subsequently, the memory difficulties of these two groups of people have many similar characteristics, including intact recognition and impaired recall, poor organization of material to be remembered, difficulties with

spatiotemporal memory, increased sensitivity to the effects of proactive interference, and perseveration of material to be remembered.

Recall versus recognition. Poor free recall and normal (or near-normal) recognition characterize the memory performance of people with frontal lobe lesions (Jetter et al., 1986; Moscovitch, 1989) and healthy older subjects (Craik et al., 1987; Salthouse, 1980). This recall-recognition difference is thought to reflect a decreased need for the subject to generate and utilize retrieval cues when recognition procedures are used to test memory (Craik, 1977). By removing the necessity for self-initiated generation of cues, the apparent memory difficulties of subjects with poor executive functioning skills are eliminated or reduced. This supports the idea that executive difficulties (i.e., initiation and concept formation) contribute to the memory difficulties in these subjects.

Organization. As previously discussed, organization and elaboration of information aids in long-term retention of that material (e.g., Craik & Lockhart, 1972). In contrast to young unimpaired subjects, older subjects and those with frontal-lobe lesions do not appear to engage spontaneously in this type of organization (e.g., McDowall, 1979; Poon, 1985). It is apparent that at least part of the memory difficulties in these two populations are due to inefficient organization of the information to be remembered. This has been illustrated in studies demonstrating improved memory performance when the material to be remembered is inherently organized and when the use of organizational strategies is encouraged.

Differences between memory for organized and unorganized material, first of all, indicate that executive difficulties have a notable effect on memory. Presumably, memory for unorganized material would be more greatly affected by executive difficulties because it requires more effortful processing than organized material (see Craik, 1983). Among healthy older adults, age differences in memory performance are increased when the material to be remembered is poorly organized (reviewed in Craik, 1977; Kaszniak, Poon, & Riege, 1986). For example, age differences are more apparent on memory tests for word lists than for short stories (Mitrushina & Satz, 1989) and for texts made up of sentences in a jumbled order rather than the normal order (Byrd, 1981, reported in Craik, 1983). Age-related memory differences are also more pronounced for lists of words from many categories than for lists of words taken from a single category (Laurence, 1967). Furthermore, age differences in memory are greater for word pairs of low association value (e.g., key-horse) than for word pairs of higher association value (e.g., book-school; Craik et al., 1987). These studies suggest that the need to organize material has a disproportionately detrimental effect on the abilities of older people to successfully remember that information. Similar studies with frontal-lobe patients are lacking, although one might expect them to yield comparable results.

Another way to examine the effect of executive difficulties on memory performance is to look for the spontaneous use of organizational strategies on memory tasks. Older unimpaired adults and younger adults with frontal-lobe

injury do not appear to use organizational strategies such as mnemonics, imagery, elaboration, or association to the same extent as younger healthy people; this failure to organize results in poorer memory performance (della Rocchetta, 1986; Hirst & Volpe, 1988; Salthouse, 1980). Thus, when organizational strategies are task-driven or are encouraged by the experimenter, memory difficulties diminish. In one study with frontal-lobe-injured subjects, free recall of word lists approximated that of controls when the experimenter helped the subjects to arrange the words into semantic categories during acquisition (Hirst & Volpe, 1988). Similarly, in a study with healthy older subjects, age differences were considerably smaller when the experimenter encouraged subjects to use an overlearned organizational strategy (i.e., alphabetizing) than when no such encouragement was given (Hultsch, 1969). In another study, age differences were eliminated when the recall task was preceded by asking subjects to sort words into categories rather than merely inspecting them (Hultsch, 1971). Requiring frontal-lobe-injured and healthy older subjects to organize material to be remembered, therefore, results in improved memory for that material.

Use of organizational strategies on memory tasks has also been investigated with Craik and Lockhart's (1972) depth of processing (DOP) approach. In this paradigm, a list of words is presented and the subject is required to engage in one of three types of analysis (i.e., structural, phonemic, or semantic) by answering questions about each word. These three types of analyses are thought to require progressively deeper levels of processing. After this

preliminary task, subjects are given an unexpected recall test of the words presented. In general, deeper levels of processing are associated with higher levels of recall because they result in more of the elaborate stimulus encoding that is thought to be necessary for effective retrieval (Craik & Lockhart, 1972; Craik & Tulving, 1975).

A number of studies using the DOP framework have indicated that age differences in recall are greatly reduced under the semantic analysis condition (in Craik, 1977; Craik & Simon, 1980; Smith, 1980). This suggests that age-related differences in recall are at least partially attributable to the spontaneous use of different types of processing strategies by younger and older subjects. When older subjects are "forced" to adopt a more effective type of processing, they perform as well as younger subjects.

DOP studies also implicate organizational encoding deficits in subjects with frontal-lobe dysfunction, although the findings are less clear. Some studies have indicated that, unlike the case with unimpaired subjects, semantic analysis does not result in improved recall in frontal-lobe injured subjects, reflecting a severely deficient semantic-encoding capacity (e.g., Cermak & Reale, 1978; Zatorre & McEntee, 1983). Other studies, however, have demonstrated slightly improved recall under the semantic condition, although recall did not reach the level of unimpaired controls (McDowall, 1979; Squire, 1982). Thus, although these studies are consistent with semantic encoding deficits in patients with frontal-lobe

dysfunction, the patterns of performance are still unclear (see Butters & Miliotis, 1985).

Overall, studies of information organization indicate that inefficient organization can result in impoverished performance on memory tests. It is apparent that healthy older subjects fail to engage adequately in organization and elaboration of material and that their memory performance is subsequently limited. The case is less clear for subjects with known frontal-lobe damage, but sufficient evidence is available to suggest that a similar processes may be occurring.

Spatiotemporal memory. Another memory feature of healthy older and frontal-lobe-injured subjects is poor memory for spatial and temporal information. In general, this is demonstrated by greater difficulties in recall of the spatiotemporal context of information acquisition than for recall of the content of the information itself. This type of memory difficulty is thought to be related to frontal lobe functioning (Lewis, 1989; Squire, 1987). Spatiotemporal memory in these two populations has been tested in studies examining reconstruction of temporal order, recency estimation, and source amnesia.

Memory for temporal order has been measured with a wide variety of laboratory tasks. In one procedure, two lists of items are presented at different times; later, each item is again displayed and the subject is asked to identify the list on which the item was originally presented. Significant difficulties on these types of tasks are evident in people with frontal-lobe dysfunction (Parkin, Leng,

Stanhope, & Smith, 1988; Squire, 1982) and in healthy older adults (McCormack, 1984). Memory for temporal order has also been tested by requiring subjects to reproduce word lists in the order in which they were presented. Again, below-average performance has been demonstrated among frontal-lobe patients (Shimamura, Janowsky, & Squire, 1990) and among healthy older adults (Kausler, Salthouse, & Sauls, 1988). In further studies of the older adult population, age differences were evident for memory of the temporal ordering of simple actions (Kausler & Wiley, 1990) and cognitive tasks (Kausler, Lichty, & Davis, 1985) performed in the laboratory. It is apparent, therefore, that both healthy aging and frontal-lobe dysfunction are associated with difficulties in memory for temporal order.

Recency estimation is another task used to measure spatiotemporal memory. In this type of task, a number of stimuli (e.g., pictures or words) are presented individually or in pairs. During the test phase, pairs of items are presented and the subject is asked to indicate which item was displayed most recently. Poor performance on this task has been demonstrated in subjects with frontal-lobe dysfunction (Milner, 1982) and in healthy older subjects (McCormack, 1982; Mittenberg et al., 1989).

Spatiotemporal difficulties are also indicated by the presence of source amnesia. Source amnesia has been defined as "the retrieval of experimentally-presented information without any recollection of the episode in which it was acquired" (Schacter, Harbluk, & McLachlan, 1984, p. 593). A commonly used

procedure for testing source amnesia was developed by Schacter et al. (1984) who presented trivial facts to subjects via a variety of sources (e.g., people, videotape, or overhead projector). After a delay, subjects were required to answer questions about the facts presented and to indicate the source of the information. Source amnesia was indicated when subjects correctly recalled the fact and misidentified its source.

Occasional source errors appear to be a normal phenomenon in delayed memory tasks (McIntyre & Craik, 1987; Schacter et al., 1984). Higher rates of source errors, on the other hand, are thought to be related to frontal-lobe functioning. People with known damage to the frontal lobes tend to make numerous source errors (Janowsky, Shimamura, & Squire, 1989; Parkin et al., 1988). In addition, source amnesia is statistically correlated with psychometric tests of executive functioning such as verbal fluency and the Wisconsin Card Sorting Test (Craik, Morris, Morris, & Loewen, 1990; Schacter et al., 1984; Squire, 1982). It is apparent, therefore, that source amnesia is related to poor frontal-lobe functioning.

Similar to people with known frontal-lobe damage, healthy older adults also make a high number of source errors (Craik et al., 1990; Janowsky et al., 1989; McIntyre & Craik, 1987). Both the number and type of source errors differ between young and older subjects (McIntyre & Craik, 1987). Young subjects tend to make few source errors, primarily intraexperimental ones (i.e., attributing the information to the wrong experimental source). Older subjects, on the other

hand, tend to make numerous, primarily extraexperimental, source errors (e.g., incorrectly attributing the source to outside of the experiment). The latter errors are also predominant in the performance of people with known brain dysfunction (Schacter et al., 1984). The findings that source amnesia is related to frontal dysfunction and that healthy older subjects make source errors similar to people with frontal-lobe damage support the idea that age-related differences in executive functioning may contribute to memory difficulties in older subjects.

Proactive interference. Proactive interference (PI) is the detrimental effect that previously-learned material has on attempts to acquire new information. Both frontal-lobe-damaged and healthy older adults show an increased susceptibility to PI (Parkin & Walter, 1991; Stuss et al., 1982) and a failure to release from PI (Moscovitch, 1982; Moscovitch & Winocur, 1983).

PI in memory performance has been assessed using the consonant trigram task (Peterson & Peterson, 1959). On this task, a triad of letters, numbers, or words is presented to the subject. Before recalling the triad, the subject is required to engage in a distracting task such as counting backwards from a given number for a specified amount of time. A number of trials are administered, and proactive interference is indicated by prior-list intrusions on subsequent trials. Significant difficulties with this task are evident in subjects with frontal-lobe damage (Stuss et al., 1982) and in healthy older subjects (Parkin & Walter, 1991), indicating an increased susceptibility to PI in these populations.

PI has also been examined with Wickens's method (1970) and other variations of this technique. In this method, four trials of the consonant trigram task are presented, and on the fifth trial, the class of information presented for recall is changed (i.e., there is an alphanumeric or categorical shift in the stimuli). In a variation of this method, longer lists of words are presented and the distracting task is omitted. A build-up of proactive interference is indicated by progressively lower levels of recall on the first four trials, and release from PI is indicated by a return to a high level of recall after the shift in class of information.

Failure to release from PI appears to be related to frontal-lobe dysfunction. Unimpaired people and amnesiacs without frontal damage typically show a build-up of PI and a consequent release from PI after the shift (Moscovitch & Winocur, 1983; Squire, 1982; Wickens, 1970). A failure to release from PI, on the other hand, has been documented in a variety of subjects with frontal-lobe dysfunction, including those with traumatic head injury (Zatorre & McEntee, 1983), Korsakoff amnesia (Cermak, Butters, & Moreines, 1974; Freedman & Cermak, 1986; Squire, 1982), and frontal lobectomy (Moscovitch, 1982). In addition, failure to release from PI has been noted in institutionalized older adults with no known cognitive or neurological impairments (Moscovitch & Winocur, 1983).

A failure to release from PI after a taxonomic shift is thought to reflect nonsemantic encoding of the stimuli (see Cermak et al., 1974; Wickens, 1970). It

appears, therefore, that frontal-lobe-damaged and healthy older subjects perform similarly on PI tasks, most likely reflecting a tendency to engage in a superficial encoding of the physical features of the stimuli rather than a more elaborate encoding of the semantic features.

Perseverations. Another characteristic of memory performance in people with frontal-lobe damage and in healthy older adults is an increased tendency to perseverate on the material to be remembered. Perseveration has been defined as the inappropriate continuation or recurrence of a particular activity or response (Sandson & Albert, 1984). In memory tests, perseverations appear as insertions of previously-learned material into reproductions of subsequently-presented material.

Most studies indicate that people with frontal-lobe damage tend to make more perseverations on memory tasks than people with non-frontal damage. This pattern has been demonstrated on tests of recall for a variety of stimuli, including words, sentences, paragraphs, and visual designs (Jetter et al., 1986; Luria, 1971; Novoa & Ardila, 1987). Similarly, healthy older subjects make more perseverations than younger subjects on memory tests for word lists (Moscovitch & Winocur, 1983) and visual designs (Veroff, 1980). In one study, however, a lack of perseverations in healthy older subjects was noted (Jacobs, Troster, Butters, Salmon, & Cermak, 1990). The reason for the discrepancy between these studies is unclear, but most likely reflects differences in the stimuli used.

Summary of findings. It is apparent that patients with executive dysfunction due to frontal-lobe lesions perform poorly on a number of memory tasks. Among the healthy older-adult population, thus, it is possible that age-related differences in executive functioning contribute to difficulties in memory performance. Evidence for this view is derived from specific features of frontal dysfunction that interfere with performance on memory tasks, including poor organization and elaboration of information at encoding, a heightened susceptibility to interference, and perseveration. Further evidence can be obtained by examining the similarities in memory performance by frontal-lobe-damaged and healthy older adults. In addition to the above characteristics, both groups also exhibit better recognition than free recall, and have relative difficulties with spatiotemporal memory. It does seem possible, therefore, that part of the documented age-related difference in memory performance is due to difficulties in executive functioning. The present study was designed to examine this possibility in more detail.

Overview of Present Research

In the present study, the relationship between age-related differences in executive functioning and age-associated differences in recent memory was examined. A group of healthy older adults were given two memory tests (i.e., the Rey-Osterrieth Complex Figure and the California Verbal Learning Test [CVLT]) and three tests of executive functioning (i.e., the Visual-Verbal Test, the Hooper

Visual Organization Test, and the Stroop task). These particular executive tests were chosen because the abilities they involve appear to be related to performance on the memory tasks. That is, concept formation, as measured by the Visual-Verbal Test, may be necessary for discovering the relationships between the stimuli to be remembered and, thus, for optimally organizing the information at encoding. The ability to integrate parts into a whole, as measured by the Hooper Visual Organization Test, may be necessary for the organization of complex visual information at encoding. Finally, inhibition of a dominant response, as measured by the Stroop task, may be necessary so that familiar but incorrect answers will not be generated during retrieval.

As additional measures of executive abilities, the organizational strategies used on the two memory tasks were evaluated. On the Complex Figure, use of "good continuation" and "symmetry" was assessed during the encoding phase; these organizational strategies are strongly related to recall of the Figure and are utilized less frequently with advancing age (Bennett-Levy, 1984). On the CVLT, the use of "semantic clustering" during the learning phase was examined. This strategy is thought to be related to the ability to recall the items (discussed in Delis et al., 1987).

The data were analyzed within the framework of a mediational model (Baron & Kenny, 1986). That is, executive functioning was hypothesized to mediate the relationship between age and performance on memory tests. As competing hypotheses, the roles of attention and information storage in age-

related memory differences were also examined. If attention and/or information storage is significantly related to age, then memory performance could conceivably be affected by age-related differences in these abilities.

METHODS

Subjects

Fifty-one subjects between the ages of 60 and 91 years participated in the study. Subjects were recruited via newspaper advertisements (43% of the final sample), flyers placed in local community centers, condominiums, and retirement residential buildings (16%), talks given at group meetings in community centers (12%), and word of mouth (29%).

All subjects were carefully screened via a personal interview for background factors that could affect cognitive functioning, including any history of neurologic or psychiatric disorder, learning disability, or substance abuse (based on questionnaire by Christensen, Moye, Armson, & Kern, 1992; see Appendix). Subjects were also asked to rate their current health on a four-point scale (i.e., 1 = excellent, 2 = good, 3 = fair, or 4 = poor); these self-ratings have been found to correlate highly with physicians' ratings based on medical examinations (LaRue, Bank, Jarvik, & Hetland, 1979). Furthermore, subjects were questioned about their daily activities, and each reported regular involvement in physical, mental, and/or social activities (e.g., exercising, reading the newspaper, doing crossword puzzles, babysitting grandchildren). Thirteen potential subjects were not included in the sample. Six of these were excluded because of their medical histories (i.e., cancer, stroke, transient ischemic attack, electroconvulsive therapy, serious heart attack, and head injury), five were excluded because of elevated scores on the

Geriatric Depression Scale, and two were excluded because of low scores on the Mini Mental Status Exam (described later).

Demographic information for this sample is listed in Table 1. To provide age-specific information, data in the table are listed by decade. The data indicate that there were an approximately equal number of subjects in each decade, and the mean age was 73.5 years. The sample consisted of a high proportion of female subjects (71%) and was apparently well educated with a mean 13.0 years of education. Furthermore, the mean health rating was between "excellent" and "good".

Table 1
Demographic Information

| | Decade | | | |
|--------------------------------------|--------|-------|-------|-------|
| | 60-69 | 70-79 | 80-91 | All |
| Number of subjects | 19 | 17 | 15 | 51 |
| Females:Males | | | | |
| Number | 14:15 | 12:5 | 10:5 | 36:15 |
| Percentage | 74:26 | 71:29 | 67:33 | 71:29 |
| Age | | | | |
| Mean | 65.1 | 74.1 | 83.7 | 73.5 |
| SD | 3.2 | 3.1 | 3.6 | 8.3 |
| Range | 60-69 | 70-79 | 80-91 | 60-91 |
| Years of education | | | | |
| Mean | 13.5 | 13.1 | 12.2 | 13.0 |
| SD | 3.1 | 2.1 | 3.2 | 2.8 |
| Range | 9-21 | 9-16 | 7-21 | 7-21 |
| Self-rated health^a | | | | |
| Mean | 1.4 | 1.8 | 1.8 | 1.6 |
| SD | 0.5 | 0.6 | 0.7 | 0.6 |
| Range | 1-2 | 1-3 | 1-3 | 1-3 |

Note. SD = standard deviation. ^a 1 = excellent, 2 = good, 3 = fair, 4 = poor.

Materials

A battery of tests was used to assess general cognitive abilities, mood, memory, and executive functioning.

Tests of general cognitive abilities and mood. The following four tests were used:

1. Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975). The MMSE is a brief measure of cognitive functioning. It contains 11 items assessing orientation to time and place, immediate and delayed item recall, attention, language skills, and design copying. Folstein et al. (1975) have provided evidence for the reliability and validity of the MMSE. In the present study, the MMSE was used as a screening device for abnormal cognitive decline. Individuals scoring below the standard cutoff of 25/30 were not included in the study.

2. WAIS-R Vocabulary (Wechsler, 1981). This test is a measure of verbal intelligence and is the WAIS-R subtest having the highest correlation with overall IQ (Wechsler, 1981). Evidence of the reliability and validity of the WAIS-R subtests was provided by Wechsler (1981). On this test, the subject is asked to orally define 35 words; the test is discontinued early if the subject makes five consecutive errors. Each definition is scored 0, 1, or 2 points, and the maximum total score is 70. Scores obtained from the Vocabulary test were used to verify that verbal abilities did not differ consistently with age. Typically, no age

differences among younger and older adults are found on this test (e.g., Koss et al., 1991; Ryan, Paolo, & Brungardt, 1990).

3. WAIS-R Digit Span (Wechsler, 1981). The Digit Span subtest is frequently used as a simple measure of attention (Lezak, 1983). The "digits forward" part of the subtest was used in the present study; subjects were simply required to repeat increasingly larger strings of orally-presented digits in the same order in which they were presented. The maximum number of digits correctly repeated by the subject (i.e., 3 to 9) was recorded. These scores were examined to ascertain that general performance by the older subjects was not limited by poor attention capacity. Maximum forward digit span typically falls within the average range of 7 ± 2 for older as well as younger adults (Botwinick & Storandt, 1974; Mitrushina & Satz, 1989), reflecting a stability of simple attention skills into late adulthood.

4. Geriatric Depression Scale (Brink, Yesavage, Lum, Heersema, Adey, & Rose, 1982). On this self-rating scale, subjects answer 30 yes-or-no questions about their current mood. Evidence of the scale's reliability and validity for use with older adult populations has been provided by the authors (Yesavage et al., 1983). In the present study, this scale was used as a screening measure for depression; subjects obtaining a score above the usual cutoff of 10 points were not included in the sample.

Memory tests. Two tests were used to examine memory abilities:

1. CVLT (Delis et al., 1987). This is a learning and memory task in which 16 "shopping list" items are orally presented to the subject. Delis et al. (1987) provided evidence of the reliability and validity of the CVLT. The items on the test are taken from four categories (of which the subject is not informed) and are presented in a disorganized order. The list of words is presented five times, and after each presentation the subject is asked to recall as many items as possible. Subsequently, there is an interference trial in which a new list of items is presented. The standard protocol for the CVLT calls for short-delay free- and cued-recall trials and 20-minute-delay free- and cued-recall and recognition trials. In the present study, the cued-recall trials (i.e., those in which the subject is given the four categories from which the words were taken in order to aid recall) were omitted. This was done so that the subjects' organizational strategies would not be influenced by the experimenter-provided categories.

Scores from the long-delay free-recall trial were used as the measure of memory because, as previously discussed, age-related differences in memory are most apparent on free-recall trials and after long intervals (Albert, 1988; Craik, 1977; Poon, 1985). In addition, as a measure of storage, the recognition discriminability index from the recognition trial was used. This score is a measure of the ability to distinguish target words from distractor words, and takes into consideration both correct and incorrect responses. Consequently, discriminability is considered to be a better indication of storage than is the number of correctly

identified target words (Delis et al., 1987). It is calculated with the following equation:

$$\text{Discriminability} = [1 - (\text{False positives} + \text{Misses}) / \text{Total}] \times 100$$

where Total is the number of items presented on the recognition trial (i.e., 44).

2. Rey-Osterrieth Complex Figure Test (Osterrieth, 1944; Rey, 1941) as reported in Spreen and Strauss (1991). This is a complex design used to test visual memory. The subject is first asked to copy the design; without prior warning, he or she is asked to reproduce the design from memory immediately after copying it and again after a 30-minute delay. The Taylor criteria (reported in Spreen & Strauss, 1991) were used for scoring the accuracy of the drawings. In this scoring system, the correctness and placement of 18 details of the figure are evaluated, and the maximum points obtainable is 36. Berry et al. (1991) presented data on the reliability and validity of this test with a well-educated older adult sample.

The score for the 30-minute-delay trial was used as the measure of long-term recall. As a measure of storage, the percent of details retained between the immediate and 30-minute recall trials was calculated as follows:

$$\text{Storage} = (\text{Delayed recall score} / \text{Immediate recall score}) \times 100.$$

Tests of executive functioning. The following tests and scores derived from performance on the memory tests were used as measures of executive functioning:

1. **Visual-Verbal Test (Feldman & Drasgow, 1951).** The Visual-Verbal Test was used to assess concept formation and cognitive flexibility. This test was originally developed to examine cognitive functioning in schizophrenic patients (Feldman & Drasgow, 1951), but has also been used in other populations (e.g., healthy older adults in Albert et al., 1990). Although a minimal amount of psychometric data is available, the reliability and validity of the Visual-Verbal Test have been generally supported (Feldman & Drasgow, 1951). On this task, the subject is shown 42 cards, each with four items on it, one at a time. The items on each card vary along a number of dimensions such as color, size, shape, orientation, and meaning. On each card, the subject is required to determine one way in which three of the items are alike, and then a different way in which three items are alike. The total score is the number of concepts (out of a possible 84) that are correctly named.

In order to eliminate the contaminating effects of memory on performance on this test, the original instructions were elaborated as necessary for each subject, and reminders of these instructions were given when appropriate throughout the test. Furthermore, because motor and cognitive speed tend to decrease with age (Birren & Renner, 1977; Salthouse, 1985), no time limits for responses were imposed. These modifications were implemented so that the test scores of the

older subjects would not be confounded by poor memory or slowed response times.

The Wisconsin Card Sorting Test (Heaton, 1981) is a similar task which, like the Visual-Verbal Test, assesses concept formation and cognitive flexibility. Despite the fact that the Wisconsin Card Sorting Test is the more widely used measure, the Visual-Verbal Test was chosen for the present study because it does not appear to rely as heavily on intact memory abilities.

2. Isolate responses on the Hooper Visual Organization Test (HVOT; Hooper, 1958). The HVOT is a measure of the ability to integrate parts into a whole. It consists of 30 line drawings of objects that have been cut up and rearranged, and subjects are required to mentally rearrange the pieces in order to identify each object. Limited information on the reliability and validity of the HVOT is available (Spreen & Strauss, 1991). Overall performance on the HVOT declines substantially with advancing age (Tamkin & Jacobsen, 1984; Wentworth-Rohr, Mackintosh, & Fialkoff, 1974).

The presence of a specific type of error, the isolate response, has been used as an indication of poor executive functioning (Albert & Kaplan, 1980; Lezak, 1983). Isolate responses are those in which all of the pieces of the puzzle are not used in formulating an answer (e.g., one segment of the "cane" is identified as a "pencil"). These responses are thought to reflect a tendency to segment stimulus information rather than to integrate it into a whole. Because only limited use has been made of this measure, possible age-related differences

in the number of isolate responses in the present study were examined to determine the appropriateness of their inclusion in subsequent analyses.

3. The Regard (1981) version of the Stroop (1935) task. This is a test of the ability to inhibit a dominant response in favor of a less common one. The subject is required to: (a) name the color of dots printed in blue, red, green, and yellow; (b) name the color of the ink in which a series of common words is printed; and (c) name the color of the ink in which a series of color words is printed. On the third task, the color words are printed in conflicting colors (e.g., the word "red" is printed in blue ink). The score on each trial is the amount of time required to correctly name the colors of the stimuli. An interference score is calculated as the ratio between the time required to name the colors of the color words and the time to name the colors of the dots. High scores reflect difficulties in inhibiting the dominant reading response in favor of the unusual response of color naming. The reliability and validity of this task is discussed by Spreen and Strauss (1991).

4. Semantic clustering on the CVLT. Semantic clustering is indicated by consecutive recall of two or more items from the same category, and reflects the use of a categorical organizational strategy (Delis et al., 1987). For each subject in the present study, the percentage of items on the five learning trials recalled within semantic clusters was calculated.

5. Strategy on the Complex Figure (Bennett-Levy, 1984). Perceptual organization of the Complex Figure at encoding has been analyzed with measures

of "good continuation" and "symmetry." Good continuation is indicated when a straight line is drawn in its entirety as one piece (e.g., the horizontal vertex of the rectangle is drawn as one piece through the rectangle and the adjacent triangle). In Bennett-Levy's scoring system, there are 18 places on the figure at which points for good continuation may be acquired. Symmetry, on the other hand, is indicated when symmetrical units of the figure are drawn consecutively (e.g., the subject draws one diagonal vertex immediately after drawing the other diagonal vertex). Similar to the measure of good continuation, a subject can obtain up to 18 points for symmetry, for a total strategy score of 36.

Procedures

Subjects were tested in the location of their choice: 31% chose to be tested at the University of Victoria, and the remaining 69% were tested in their homes. For those sessions occurring at home, interruptions were minimized by testing in a quiet room in the house, taking the telephone off the hook, etc. In general, interruptions of any type were infrequent and rarely problematic. Sessions lasted approximately two hours per subject. Three of the subjects (6% of the sample) preferred to do the testing in two one-hour sessions on different days; the remainder of the subjects completed the tests in one session.

Tests were administered in the following order: (a) MMSE, (b) Stroop task, (c) Complex Figure copy and immediate recall, (d) CVLT learning, interference, and short-delay trials, (e) Vocabulary subtest, (f) CVLT long-delay

free recall and recognition, (g) Complex Figure long-delay recall, (h) Digit Span, (i) Hooper Visual Organization Test, (j) Visual-Verbal Test, and (k) Geriatric Depression Scale. Following the Vocabulary test, a short break was provided until the 20-minute delay period for the CVLT expired. This specific order of test administration was chosen in order to provide the subject with some diversity (i.e., visual and verbal tasks were partially alternated) and to minimize interference of test material on the delayed recall trials.

Plan of Analysis

To test for age-related differences in demographics and general functioning, Pearson correlations were computed examining the relationship of age with education, gender ratio, health self-ratings, Vocabulary, and maximum forward digit span. A mediational model (Baron & Kenny, 1986) was used to test the hypothesis that age-related differences in executive functioning (EF) contributed to differences in memory performance. This type of analysis involves performing regressions on the age, executive functioning, and memory variables.

Composite scores. To use a mediational model analysis, it was first necessary to reduce the memory and EF scores to two composite scores so that each could be used as a criterion variable in regression analyses. This was done by standardizing the appropriate test scores (based on the scores obtained by the entire subject sample) and then adding the resulting z scores. The sign of the z score for the Stroop interference was changed so that, consistent with the other

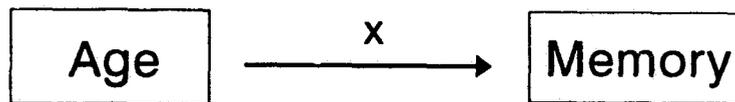
measures, positive numbers represented better performance. The recent-memory composite, therefore, was calculated as the sum of the *z* scores for the CVLT long-delay free recall and the Complex Figure long-delay recall. The EF composite was calculated as the sum of the *z* scores for the Visual-Verbal Test, Stroop interference, CVLT semantic clustering, and Complex Figure strategy. These resulting composite scores were used in the subsequent analyses. In addition, an information-storage composite score was calculated as the sum of the *z* scores for CVLT discriminability and Complex Figure retention.

The grouping of test scores into these composites was based on the construct validities of the tests and/or the general acceptance of these types of tasks as measures of the appropriate construct (e.g., Albert, Wolfe, & Lafleche, 1990; Lezak, 1983; Poon, 1985; Stuss & Benson, 1986). The method of summed *z* scores was chosen over factor analysis or principle components analysis because of the expected correlations between memory and executive functioning task performance. Whereas these latter statistical methods would have the desired effect of validating the grouping of the task scores and indicating the appropriate weights of the scores, they would also have the effect of making the factors independent of each other and thus inappropriate for mediational model analysis.

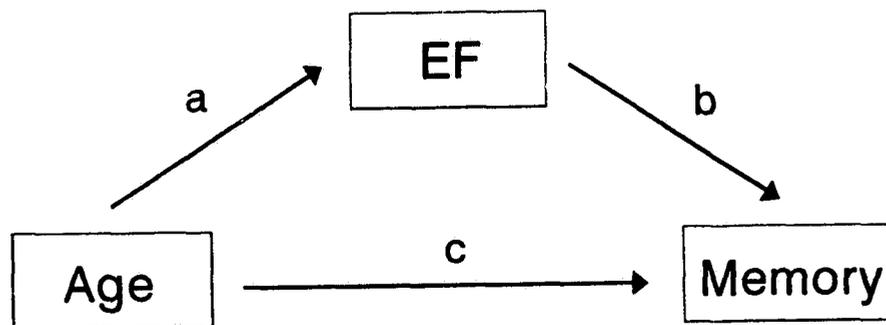
Mediational model. Figures 1a and 1b depict the two models used in the mediational model analysis. The nonmediated model (Figure 1a) portrays the well-documented pathway between age and recent-memory performance (i.e., age predicts memory performance). In this model, there are no additional variables

Figure 1. Models used to test mediation.

a. Nonmediated model



b. Mediator Model



present that may account for the relationship between age and memory. In the mediational model (Figure 1b), EF is hypothesized to mediate the relationship between age and recent-memory performance. According to this model, age has a direct effect on EF (path a), and EF has a direct effect on memory (path b). There are two possible pathways between age and memory: age may have an indirect effect on memory performance via EF, and age may have a direct effect on memory performance that is not mediated by EF (path c).

To examine whether EF mediates the effect of age on recent-memory performance, several regressions were performed. Evidence for such a mediation effect would be the following (Baron & Kenny, 1986):

1. The direct effect of age on memory (Figure 1, path x) must be significant, indicating that age predicts memory when no other variables are considered. This was tested by performing a regression with age as the predictor of the memory composite score, and examining the standardized regression coefficient (i.e., the beta weight, β) for age (Pedhazer, 1982).

2. The direct effect of age on EF (path a) must be significant. In other words, age must predict EF. This was tested by performing a regression with age as the predictor of the EF composite score, and examining the beta weight for age.

3. The direct effect of EF on memory (path b) must be significant, indicating that EF predicts memory performance. This was tested using a regression with age and EF as the predictors of the memory composite score, and

examining the beta weight for EF. (A beta weight for age was also obtained from this regression; this was used in a subsequent comparison.)

After all of these preliminary relationships were confirmed, the mediational model was tested as follows (Baron & Kenny, 1986):

1. The effect of age on memory was compared between the first equation (path x , in which the effect of EF was not considered) and the third equation (path c , in which the effect of EF was partialled out of the equation). Mediation is indicated when the beta weight for age is greater in the first equation than in the third. The strongest evidence of a mediation effect occurs when the beta weight is significant in the first equation and nonsignificant in the third, indicating that after accounting for EF, age is not a significant predictor of memory performance.

2. The absolute size of the indirect pathway between age and recent-memory performance via EF was examined to determine whether this represented a significant indirect effect. The indirect effect of age on memory was calculated as the product of the direct effects of age on EF and of EF on memory (Cohen & Cohen, 1983). To test for the significance of the indirect effect, a t score was calculated as follows (Baron & Kenny, 1986):

$$\frac{ab}{\sqrt{a^2 s_b^2 + b^2 s_a^2 + s_a^2 s_b^2}}$$

where a and b are the direct path coefficients, and s_a and s_b are the standard errors of those coefficients. The numerator of this equation is the indirect effect, and the denominator is the standard error of the indirect effect.

RESULTS

General Test Performance

Scores obtained on the various psychometric tests are summarized in Table 2. For ease of examining age differences in performance, the mean scores for subjects in each decade are presented separately. Overall, subjects scored at or above the expected ranges on the tests with available age-corrected normative data. The mean score obtained on the Vocabulary subtest was approximately 60 points, which places these subjects at about the 90th percentile in comparison to their age peers (Ryan et al., 1990; Wechsler, 1981). Maximum forward digit span was at the expected level, with a mean of 6 or 7 digits correctly repeated; this level of performance falls well within the normal range of 7 ± 2 (Botwinick & Storandt, 1974). Memory recall was also at the expected level as measured by performance on the CVLT long-delay free-recall trial (mean score was 10 points, 50th percentile; Delis et al., 1987) and on the long-delay recall trial of the Complex Figure (16 points, 44th percentile; Berry et al., 1991)

Table 2

Mean Test Performance on Measures of General Functioning, Memory, and Executive Ability

| Test | Decade | | | |
|------------------------|-------------|-------------|--------------|-------------|
| | 60-69 | 70-79 | 80-91 | All |
| MMSE | 28.8 (0.8) | 28.8 (1.3) | 28.4 (1.5) | 28.7 (1.2) |
| GDS | 3.6 (2.4) | 5.1 (3.4) | 5.6 (2.6) | 4.7 (2.9) |
| Vocabulary | 61.2 (5.4) | 60.0 (4.0) | 57.9 (6.3) | 59.8 (5.4) |
| Maximum Digit Span | 7.2 (1.2) | 6.4 (1.1) | 6.3 (1.0) | 6.7 (1.2) |
| CVLT | | | | |
| Long-Delay Recall | 11.2 (3.6) | 10.2 (3.4) | 9.5 (2.8) | 10.4 (3.3) |
| Discrimination | 95.8 (4.3) | 94.0 (4.9) | 91.1 (7.9) | 93.8 (6.0) |
| Semantic Clustering | 44.8 (18.7) | 37.3 (18.5) | 33.7 (14.0) | 39.1 (17.7) |
| Complex Figure | | | | |
| Long-Delay Recall | 18.9 (5.9) | 15.7 (6.0) | 13.9 (4.1) | 16.4 (5.8) |
| Retention (%) | 98.2 (11.6) | 95.7 (14.3) | 101.4 (15.7) | 98.3 (13.7) |
| Strategy | 24.0 (4.6) | 23.7 (5.7) | 20.8 (5.5) | 23.0 (5.4) |
| Visual Verbal Test | 75.5 (3.7) | 72.5 (5.1) | 67.9 (8.9) | 72.3 (6.7) |
| Stroop Interference | 2.2 (0.4) | 2.6 (0.7) | 3.2 (1.1) | 2.6 (0.9) |
| HVOT Isolate Responses | 0.7 (0.9) | 1.1 (0.9) | 0.9 (1.0) | 0.9 (0.9) |

Note. Standard deviations are shown in parentheses. MMSE = Mini Mental State Examination, GDS = Geriatric Depression Scale, CVLT = California Verbal Learning Test, and HVOT = Hooper Visual Organization Test.

Age Differences in Demographics and General Functioning

To reduce the chance of making Type I errors, Bonferroni corrections were used for the following five correlations; the critical p value was set at $.05/5$ or $.01$. Bonferroni-corrected Pearson correlations indicated no age-related differences in demographic variables, including percentage of females ($r = -.10$, $p = .52$), years of education ($r = -.19$, $p = .20$), and self-rated health ($r = .27$, $p = .06$). Similarly, there were no significant age-related differences in Vocabulary test scores ($r = -.25$, $p = .08$), and maximum forward digit span ($r = -.30$, $p = .03$).

Isolate responses on the Hooper Visual Organization test were not related to age, as indicated by a Pearson correlation ($r = .21$, $p = .14$). Consequently, this variable was not included in the subsequent analyses. To test for age-related differences in information storage, a Pearson correlation between age and the storage composite score was calculated. This correlation was not significant ($r = -.10$, $p = .47$).

Mediational Model

The main hypothesis that age-related differences in executive functioning contribute to age-related differences in memory performance was analyzed within a mediational model (Baron & Kenny, 1986). Figures 2a and 2b show the mediational model with the data obtained in the present study. "Age" was

measured as a continuous variable, and composite scores were used as the measures of "memory" and "EF."

The previously discussed relationships indicative of a mediation effect were obtained. That is:

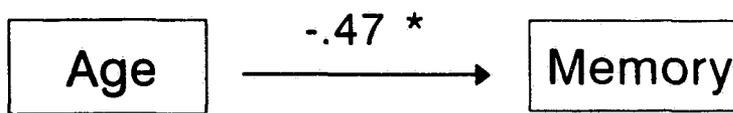
1. As shown in Figure 2a, age was a significant predictor of memory when no other variables were considered, $\beta = -.47$, standard error of $\beta = .13$, $t(50) = -3.71$, $p = .001$.
2. As shown in Figure 2b, age was a significant predictor of EF, $\beta = -.58$, standard error of $\beta = .12$, $t(50) = -4.97$, $p < .001$.
3. Finally, as shown in Figure 2b, EF was a significant predictor of memory independent of the effect of age, $\beta = .60$, standard error of $\beta = .13$, $t(50) = 4.65$, $p < .001$.

Because all of these preliminary relationships were confirmed, the model was tested further as follows (Baron & Kenny, 1986):

1. The absolute size of the effect of age on memory was greater in the first equation (Figure 2a, $\beta = -.47$, $p = .001$) than in the third equation (Figure 2b, $\beta = -.12$, $t(50) = -0.91$, $p = .37$). In addition, after accounting for EF, age was no longer a significant predictor of memory performance.

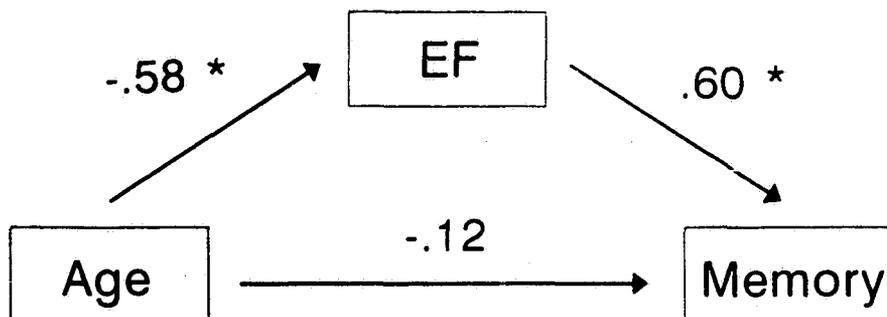
Figure 2. Models used to test mediation, with data. (Numbers shown are standardized regression coefficients.)

a. Nonmediated model



* $p < .001$

b. Mediator model



* $p < .001$

2. The indirect effect of age on memory was calculated as $-.58 \times .60 = -.35$. Results of a t test indicated that the indirect pathway was statistically significant, $t = -3.35, p < .005$. Thus, individual differences in executive functioning appeared to account for observed differences in memory recall.

Unique Contribution of EF to Memory

For purposes of examining the clinical significance of these data, the proportion of the variance in memory that was accounted for uniquely by EF and was independent of age was determined. This number was calculated as the squared beta weight for EF in the regression using age and EF as predictors of memory (i.e., $.60^2$, or .36; Cohen & Cohen, 1983). Thus, EF accounted for 36% of the variance in recent-memory-recall scores, independent of the relationship of age and recent-memory recall.

DISCUSSION

In general, test performance indicates that the participants in the present study are relatively high-functioning individuals. The vocabulary skills of these subjects are well above age norms (Ryan et al., 1990; Wechsler, 1981). Simple attention and recall from recent memory, on the other hand, are within the average range (Berry et al., 1991; Botwinick & Storandt, 1974; Delis et al., 1987).

As expected, Vocabulary, maximum forward digit span, and information storage do not show significant age-related differences in this sample, indicating no systematic age differences in verbal intellectual abilities, simple attention, or information storage. This is consistent with the general pattern reported in most studies (e.g., Benton et al., 1981; Koss et al., 1991; Mitrushina & Satz, 1989; Smith, 1980). These findings suggest that the age differences in memory performance and executive functioning reported in the present study do not reflect poorer verbal intellectual abilities, simple attention skills, or information storage in older subjects. Because neither simple attention nor information storage were strongly related to age, these variables were not examined as possible mediators of the relationship between age and memory performance.

The preliminary regression analyses indicate that age predicts the memory composite scores and that age predicts the EF composite scores. These findings are consistent with previous research indicating significant age-related differences

on tests of recent-memory recall (Bennett-Levy, 1984; Delis et al., 1987) and executive functioning (Albert et al., 1990; Axelrod & Henry, 1992).

The hypothesis that EF mediates the relationship between age and recent-memory recall is supported by the data. That is, when considered alone, there is a significant relationship between age and recent-memory recall; however, this relationship is no longer significant when the effects of EF are partialled out of the equation. Furthermore, the indirect pathway between age and recall via EF is significant, indicating that this pathway accounts for a significant proportion of the variance in memory performance in the model tested. These findings demonstrate that a major part of the age-related differences in recent-memory recall in this sample is accounted for by age-related differences in executive functioning. This is consistent with the pervasive nature of the executive functions. Executive skills are required for a wide variety of everyday cognitive functions, and their decline with age is likely to have widespread effects.

Implications

These findings may have useful applications to the clinical assessment of memory difficulties. As previously discussed, Goldberg and Bilder (1986) argued that performance on some memory tests depends on intact encoding strategies and executive control. The failure to recognize these contributions to memory tasks, furthermore, can result in incorrect conclusions about the client's true deficits. For the elderly population, this means that poor performance on a

memory test may partially reflect the increasing difficulties in executive functioning that develop with age rather than reflecting a memory deficit alone. In the present study, 36% of the variance in memory recall was accounted for by performance on the tests of executive functioning. This large contribution to recall, therefore, should be taken into consideration when interpreting older adults' performances on memory tests.

An extension of these findings would suggest that difficulties in executive ability may contribute to difficulties on other tests of neuropsychological functioning. For example, optimal performance on tests of language abilities involving retrieval of information (e.g., naming tests or word fluency) may rely somewhat on strategic retrieval and impulse inhibition. Similarly, performance on novel or complex tests of visuospatial intellectual skills such as the WAIS-R Performance subtests may require the executive abilities of hypothesis generation and cognitive flexibility. It is possible, therefore, that executive difficulties underlie poor performance in other domains of cognitive functioning.

It should be noted that the present findings do not imply that all age-related differences in performance on all memory tests are accounted for exclusively by executive functioning. Indeed, the well-established age-related deterioration in the temporal lobes of the brain (e.g., Bondareff, 1985; Creasey & Rapoport, 1985; Schiebel, 1981; Terry et al., 1987) would suggest that true difficulties in memory acquisition and retrieval are likely to develop eventually with age regardless of an individual's executive functioning abilities. In addition,

some clinical memory tests may not be confounded by requirements for intact executive functioning and, thus, poor performance on those tests would reflect true memory difficulties. In the present study, however, specific memory tasks were chosen that appeared to depend at least partially on a self-initiated, organized approach. Both the CVLT and the Complex Figure involve memory for very complicated material; therefore, subjects who initiated organizational strategies on these tasks most likely had a more effective framework from which to recall the material than subjects who used either inefficient strategies or none at all. The present study, thus, addresses the apparent memory difficulties noted on some tasks that are due to the requirement of intact executive skills (in addition to memory) for optimal performance.

Contradictory Studies

The finding that EF mediates the relationship between age and memory performance contradicts two recent studies (Janowsky & Thomas-Thrapp, 1993; Ska & Nespoulous, 1988). These studies demonstrated: (a) age-related differences in memory for the Complex Figure; and (b) a lack of age-related differences in the strategy used to draw the Figure. Thus, the authors concluded that strategy use cannot explain the age-related differences in memory for the Figure. The reason for the contradictory findings in these studies and the present study may involve the measures of strategy that were used. The previous studies used relatively simple measures (i.e., examining segmentation of only five of the

Figure's units, or simply categorizing strategies into different types); these may not have been sufficiently detailed to detect subtle differences in strategy use. More detailed measures, on the other hand, have indicated age-related differences in strategy use, such as Bennett-Levy's 36-point scale of "symmetry" and "good continuation" (1984). In the present study, multiple measures of strategy and organizational ability were used, and a significant relationship between age and this ability was obtained.

Age and Isolate Responses

The hypothesized age-related differences in the production of isolate responses on the HVOT were not obtained. There are several possible reasons for this unexpected finding. First, very few isolate responses were made overall; the mean number was less than one per subject. It is possible that these responses occurred too infrequently to detect subtle age differences, if any were present.

A second possible reason for the lack of a relationship with age is that subjects appeared to make isolate responses for different reasons. Subjects who found the task simple made occasional isolate-response errors due to answering quickly and perhaps impulsively; those who found the task difficult tended to study the stimuli more carefully and made errors due to their genuine inability to integrate the pieces into a whole. In future research, it may be useful to require

subjects to study the stimuli for a minimum amount of time before responding in order to distinguish between these types of errors.

Representativeness of the Sample

The subjects who participated in this study were somewhat atypical of their age peers. Overall, the sample contained a higher proportion of females, and was brighter and more highly educated than the general older adult population in Canada.

In the population of individuals age 60 and over, there are considerably more females than males. Statistics from the 1991 census indicate that 56.2% of Canadians age 60 and over are females. This number is slightly larger (58.0%) in the Capital Regional District of British Columbia, where the subjects in the present study live (Statistics Canada, 1992). In this study, 70.6% of the subjects were female, reflecting in part the higher number of females in the general older adult population. In addition, this high number may reflect the greater willingness of females to participate in psychological studies.

This sample also appears to consist of relatively high-functioning individuals. The average level of education for the subjects in the present study was 13.0 years. This is notably higher than the Canadian national average (9.6 years) and the British Columbia provincial average (10.8 years) for people age 65 years and older (Statistics Canada, 1993). Consistent with the high level of education, these subjects also appear to be brighter than average. Although a

thorough test of IQ was not administered, scores on the WAIS-R Vocabulary subtest correlate highly with overall intellectual ability. A comparison of the Vocabulary scores obtained by the present sample and normative samples of people age 60 and over (Ryan et al., 1990; Wechsler, 1981) indicates that all of the present subjects scored at or above the 50th percentile on this subtest, and 82% scored at or above the 90th percentile. This profusion of bright, well-educated subjects may reflect the greater willingness of people who feel confident of their abilities to participate in studies of cognitive functioning.

Although the generalizability of these results is obviously limited by the nonrepresentative nature of the sample, the importance of the main findings of this study would not appear to be diminished. If a more representative sample of subjects had been used, more drastic age-related differences in performance on the EF and memory tests would most likely have been obtained. With this increased variation in the overall performance of the sample, the model might have been supported to an even greater extent than it was with the present sample of subjects.

Directions for Future Research

The support for the mediator relationship of EF to memory performance among the healthy elderly has some implications for future research. It may be interesting to test for the mediating effect of EF on memory performance in patient populations such as dementia. A recent study (Bondi et al., 1993)

indicated that, among patients with Parkinson's Disease, memory was not significantly impaired after the effects of executive deficits were accounted for. This may also be the case for other patient populations that exhibit impairments in both memory and executive functioning. This type of research, therefore, may be helpful in determining the exact nature of the neuropsychological deficits of various patient populations.

The present research may also have implications for the cognitive rehabilitation of memory problems for people who also have executive impairments. It may be useful to teach the use of strategies such as organization and elaboration of information to be remembered. Lawson and Rice (1989) reported a case study in which training in the use of executive strategies (i.e., problem analysis, strategy formation and initiation, self-monitoring) was successful in improving verbal memory in an individual who had sustained a head injury. The present study provides theoretical support for the view that training in executive functioning may indeed result in improvements in memory performance. Further research regarding the training of executive skills for the remediation of memory impairments may be helpful in establishing the usefulness of this type of rehabilitation.

A final possibility for future research would be to create tests or paradigms useful for distinguishing between true memory deficits and those strongly influenced by impaired executive functioning. In clinical assessment, it would be helpful to know the extent to which a particular client's executive difficulties

contribute to his or her performance on memory tests so that the true nature of the deficit can be determined. One possibility would be to develop normative memory performance data for two similar tests, one which requires strategy use for optimal performance and one which does not. Greater than usual difficulties on the first test than on the second would indicate that executive difficulties may be contributing to an individual's poor memory performance.

References

- Albert, M. S. (1988). Cognitive function. In M. S. Albert & M. B. Moss (Eds.), Geriatric neuropsychology (pp. 33-53). New York: Guilford.
- Albert, M. S., Duffy, F. H., & Naeser, M. (1987). Nonlinear changes in cognition with age and their neuropsychologic correlates. Canadian Journal of Psychology, *41*, 141-157.
- 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, New Jersey: Lawrence Erlbaum.
- Albert, M. S., & Moss, M. B. (1988). Geriatric neuropsychology. New York: Guilford.
- Albert, M. S., & Stafford, J. L. (1988). Computed tomography studies. In M. S. Albert & M. B. Moss (Eds.), Geriatric neuropsychology (pp. 211-227). New York: Guilford.
- Albert, M. S., Wolfe, J., & Lafleche, G. (1990). Differences in abstraction ability with age. Psychology and Aging, *5*, 94-100.
- Axelrod, B. N., & Henry, R. R. (1992). Age-related performance on the Wisconsin Card Sorting, Similarities, and Controlled Oral Word Association tests. The Clinical Neuropsychologist, *6*, 16-26.
- Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, & statistical considerations. Journal of Personality and Social Psychology, *51*, 1173-1182.
- Bennett-Levy, J. (1984). Determinants of performance on the Rey-Osterrieth Complex Figure Test: An analysis, and a new technique for single-case assessment. British Journal of Clinical Psychology, *23*, 109-119.
- Benton, A. L. (1968). Differential behavioral effects in frontal lobe disease. Neuropsychologia, *6*, 53-60.
- Benton, A. L., Eslinger, P. J., & Damasio, A. R. (1981). Normative observations on neuropsychological test performances in old age. Journal of Clinical Neuropsychology, *3*, 33-42.

- Benton, A. L., & Hamsher K. (1977). Multilingual Aphasia Examination. Iowa City: University of Iowa.
- Berry, D. T. R., Allen, R. S., & Schmitt, F. A. (1991). Rey-Osterrieth Complex Figure: Psychometric characteristics in a geriatric sample. The Clinical Neuropsychologist, 5, 143-153.
- Bigler, E. (1988). Frontal lobe damage and neuropsychological assessment. Archives of Clinical Neuropsychology, 3, 279-297.
- Birren, J. E., & Renner, V. J. (1977). Research on the psychology of aging: Principles and experimentation. In J. E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging (pp. 3-38). New York: Van Nostrand Reinhold.
- Bolla, K. I., Lindgren, K. N., Bonaccorsy, C., & Bleecker, M. (1990). Predictors of verbal fluency (FAS) in the healthy elderly. Journal of Clinical Psychology, 46, 623-628.
- Bondareff, W. (1985). The neural basis of aging. In J. E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging (2nd ed., pp. 95-112). New York: Van Nostrand Reinhold.
- Bondi, M. W., Kaszniak, A. W., Bayles, K. A., & Vance, K. T. (1993). Contributions of frontal system dysfunction to memory and perceptual abilities in Parkinson's Disease. Neuropsychology, 7, 89-102.
- Boone, K. B., Miller, B. L., Lesser, I. M., Hill, E., & D'Elia, L. (1990). Performance on frontal lobe tests in healthy, older individuals. Developmental Neuropsychology, 6, 215-223.
- Botwinick, J., & Storandt, M. (1974). Memory, related functions, and age. Springfield, IL: Thomas.
- Brink, T. L., Yesavage, J. A., Lum, O., Heersema, P. H., Adey, M., & Rose, T. L. (1982). Screening tests for geriatric depression. Clinical Gerontologist, 1, 37-43.
- Butters, N., & Miliotis, P. (1985). Amnesic disorders. In K. M. Heilman & E. Valenstein (Eds.), Clinical neuropsychology (pp. 403-452). New York: Oxford.
- Cermak, L. S., Butters, N., & Moreines, J. (1974). Some analyses of the verbal encoding deficit of alcoholic Korsakoff patients. Brain and Language, 1, 141-150.

- Cermak, L. S., & Reale, L. (1978). Depth of processing and retention of words by alcoholic Korsakoff patients. Journal of Experimental Psychology: Human Learning and Memory, 4, 165-174.
- Christensen, K. J., Moye, J., Armson, R. R., & Kern, T. M. (1992). Health screening and random recruitment for cognitive aging research. Psychology and Aging, 7, 204-208.
- Cohen, J., & Cohen, P. (1983). Applied multiple regression/ correlation analysis for the behavioral sciences. Hillsdale, New Jersey: Lawrence Erlbaum.
- Creasey, H., & Rapoport, S. I. (1985). The aging human brain. Annals of Neurology, 17, 2-10.
- 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.
- Craik, F. I. M. (1983). On the transfer of information from temporary to permanent memory. Philosophical Transactions of the Royal Society of London (Series B), 302, 341-359.
- Craik, F. I. M., Byrd, M., & Swanson, J. M. (1987). Patterns of memory loss in three elderly samples. Psychology and Aging, 2, 79-86.
- Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 11, 671-684.
- Craik, F. I. M., Morris, L. W., Morris, R. G., & Loewen, E. R. (1990). Relations between source amnesia and frontal lobe functioning in older adults. Psychology and Aging, 5, 148-151.
- Craik, F. I. M., & Simon, E. (1980). Age differences in memory: The roles of attention and depth of processing. 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. 95-112). Hillsdale, New Jersey: Lawrence Erlbaum.
- Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. Journal of Experimental Psychology: General, 104, 268-294.

- Cullum, C. M., Butters, N., Troster, A. I., & Salmon, D. P. (1990). Normal aging and forgetting rates on the Wechsler Memory Scale-Revised. Archives of Clinical Neuropsychology, 5, 23-30.
- Damasio, A. R. (1985). The frontal lobes. In K. M. Heilman & E. Valenstein (Eds.), Clinical neuropsychology (pp. 339-375). New York: Oxford.
- Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (1987). The California Verbal Learning Test-Research Edition. New York: Psychological Corporation.
- della Rocchetta, A. I. (1986). Classification and recall of pictures after unilateral frontal or temporal lobectomy. Cortex, 22, 189-211.
- Drachman, D. A. (1986). Memory and cognitive function in normal aging. Developmental Neuropsychology, 2, 277-285.
- Drachman, D. A., & Leavitt, J. (1972). Memory impairment in the aged: Storage versus retrieval deficits. Journal of Experimental Psychology, 93, 302-308.
- Drachman, D. A., & Long, R. R. (1984). Neurological evaluation of the elderly patient. In M. L. Albert (Ed.), Clinical neurology of aging (pp. 97-113). New York: Oxford.
- Duara, R., Grady, C., Haxby, J., Ingvar, D., Sokoloff, L., Margolin, R. A., Manning, R. G., Cutler, N. R., & Rapoport, S. I. (1984). Human brain glucose utilization and cognitive function in relation to age. Annals of Neurology, 16, 702-713.
- Duffy, F. H., Albert, M. S., McAnulty, G., & Garvey, A. J. (1984). Age-related differences in brain electrical activity of healthy subjects. Annals of Neurology, 16, 430-438.
- Duffy, F. H., & McAnulty, G. (1988). Electrophysiological studies. In M. S. Albert & M. B. Moss (Eds.), Geriatric neuropsychology (pp. 262-291). New York: Guilford.
- Feldman, M. J., & Drasgow, J. (1951). A Visual-Verbal test for schizophrenia. Psychiatric Quarterly, 25 (Suppl.), 55-64.
- Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini-Mental State: A practical method for grading the cognitive state of patients for the clinician. Journal of Psychiatric Research, 12, 189-198.

- Ford, J. M., & Pfefferbaum, A. (1980). The utility of brain potentials in determining age-related changes in central nervous system and cognitive functioning. In L. W. Poon (Ed.), Aging in the 1980s (pp. 115-124). Washington, D. C.: American Psychological Association.
- Freedman, M., & Cermak, L. S. (1986). Semantic encoding deficits in frontal lobe disease and amnesia. Brain and Cognition, 5, 108-114.
- Geffen, G., Moar, K. J., O'Hanlon, A. P., Clark, C. R., & Geffen, L. B. (1990). Performance measures of 16- to 86-year-old males and females on the Auditory Verbal Learning Test. The Clinical Neuropsychologist, 4, 45-63.
- Gerard, G., & Weisberg, L. A. (1986). MRI periventricular lesions in adults. Neurology, 36, 998-1001.
- Goldberg, E., & Bilder, R. M. (1986). Neuropsychological perspectives: Retroactive amnesia and executive deficits. In L. W. Poon (Ed.), Handbook for clinical memory assessment of older adults (pp. 55-68). Washington, D.C.: American Psychological Association.
- Haaland, K. Y., Vranes, L. F., Goodwin, J. S., & Garry, P. J. (1987). Wisconsin Card Sort Test performance in a healthy elderly population. Journal of Gerontology, 42, 345-346.
- Heaton, R. K. (1981). Wisconsin Card Sorting Test manual. Odessa, FL: Psychological Assessment Resources.
- Hirst, W., & Volpe, B. T. (1988). Memory strategies with brain damage. Brain and Cognition, 8, 379-408.
- Hochanadel, G., & Kaplan, E. (1984). Neuropsychology of normal aging. In M. L. Albert (Ed.), Clinical neurology of normal aging (pp. 231-244). New York: Oxford.
- Hooper, H. E. (1958). The Hooper Visual Organization Test. Beverly Hills, California: Western Psychological Services.
- Hultsch, D. F. (1969). Adult age differences in the organization of free recall. Developmental Psychology, 1, 673-678.
- Hultsch, D. F. (1971). Adult age differences in free classification and free recall. Developmental Psychology, 4, 338-342.

- Ivnik, R. J., Malec, J. F., Tangalos, E. G., Petersen, R. C., Kokmen, E., & Kurland, L. T. (1990). The Auditory-Verbal Learning Test (AVLT): Norms for ages 55 years and older. Psychological Assessment, *2*, 304-312.
- Jacobs, D., Troster, A. I., Butters, N., Salmon, D. P., & Cermak, L. S. (1990). Intrusion errors on the Visual Reproduction Test of the Wechsler Memory Scale and the Wechsler Memory Scale - Revised: An analysis of demented and amnesic patients. The Clinical Neuropsychologist, *4*, 177-191.
- Janowsky, J. S., Shimamura, A. P., & Squire, L. R. (1989). Source memory impairments 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 constructional strategy? Journal of Clinical and Experimental Neuropsychology, *15*, 159-169.
- Jetter, W., Poser, U., Freeman, R. B., Markowitsch, H. J. (1986). A verbal long term memory deficit in frontal lobe damaged patients. Cortex, *22*, 229-242.
- Kaszniak, A. W., Poon, L. W., & Riege, W. (1986). Assessing memory deficits: An information-processing approach. In L. W. Poon (Ed.), Handbook for clinical memory assessment of older adults (pp. 168-188). Washington, D. C.: American Psychological Association.
- Katzman, R., & Terry, R. (1983). Normal aging of the nervous system. In R. Katzman & R. Terry (Eds.), The neurology of aging (pp. 15-50). Philadelphia: F. A. Davis.
- Kausler, D. H., Lichty, W., & Davis, R. T. (1985). Temporal memory for performed activities: Intentionality and adult age differences. Developmental Psychology, *21*, 1132-1138.
- Kausler, D. H., Salthouse, T. A., & Saults, J. S. (1988). Temporal memory over the adult lifespan. American Journal of Psychology, *101*, 207-215.
- Kausler, D. H., & Wiley, J. G. (1990). Temporal memory and content memory for actions: Adult age differences in acquisition and retention. Experimental Aging Research, *16*, 147-150.
- King, M. C. (1981). Effects of non-focal brain dysfunction on visual memory. Journal of Clinical Psychology, *37*, 638-643.

- Kopelman, M. D. (1989). Remote and autobiographical memory, temporal context memory and frontal atrophy in Korsakoff and Alzheimer patients. Neuropsychologia, 27, 437-460.
- Koss, E., Haxby, J. V., DeCarli, C., Schapiro, M. B., Friedland, R. P., & Rapoport, S. I. (1991). Patterns of performance preservation and loss in healthy aging. Developmental Neuropsychology, 7, 99-113.
- Kozora, E., & Cullum, C. M. (1993, February). Generative naming in normal aging: Comparison of five tasks. Paper presented at the 21th annual meeting of the International Neuropsychological Society, Galveston, TX.
- Kuhl, D. E., Metter, E. J., Riege, W. H., & Hawkins, R. A. (1984). The effect of normal aging on patterns of local cerebral glucose utilization. Annals of Neurology, 15 (suppl.), S133-S137.
- LaRue, A., Bank, L., Jarvik, L., & Hetland, M. (1979). Health in old age: How do physicians' ratings and self-ratings compare? Journal of Gerontology, 34, 687-691.
- Laurence, M. W. (1967). Memory loss with age: A test of two strategies for its retardation. Psychonomic Science, 9, 209-210.
- Lawson, M. J., & Rice, D. N. (1989). Effects of training in use of executive strategies on a verbal memory problem resulting from closed head injury. Journal of Clinical and Experimental Neuropsychology, 11, 842-854.
- Lewis, R. S. (1989). Remembering and the prefrontal cortex. Psychobiology, 17, 102-107.
- Lezak, M. D. (1983). Neuropsychological assessment (2nd ed.). New York: Oxford.
- Luria, A. R. (1971). Memory disturbances in local brain lesions. Neuropsychologia, 9, 367-375.
- Luria, A. R. (1973). The working brain: An introduction to neuropsychology. New York: Basic Books.
- Mack, J. L., & Carlson, N. J. (1978). Conceptual deficits and aging: The Category Test. Perceptual and Motor Skills, 46, 123-128.
- Mayes, A. R. (1986). Learning and memory disorders and their assessment. Neuropsychologia, 24, 25-39.

- McCormack, P. D. (1982). Temporal coding and study-phase retrieval in young and elderly adults. Bulletin of the Psychonomic Society, 20, 242-244.
- McCormack, P. D. (1984). Temporal coding by young and elderly adults in a list-discrimination setting. Bulletin of the Psychonomic Society, 22, 401-402.
- McDowall, J. (1979). Effects of encoding instructions and retrieval cueing on recall in Korsakoff patients. Memory and Cognition, 7, 232-239.
- McDowd, J. M., & Birren, J. E. (1990). Aging and attentional processes. In J. E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging (3rd ed., pp. 222-234). San Diego: Academic.
- McIntyre, J. S., & Craik, F. I. M. (1987). Age differences in memory for item and source information. Canadian Journal of Psychology, 41, 175-192.
- Michalewski, H. J., Thompson, L. W., Smith, D. B. D., Patterson, J. V., Bowman, T. E., Litzelman, D., & Brent, G. (1980). Age differences in the contingent negative variation (CNV): Reduced frontal activity in the elderly. Journal of Gerontology, 35, 542-549.
- Milner, B. (1982). Some cognitive effects of frontal-lobe lesions in man. Philosophical Transactions of the Royal Society of London, Series B, 298, 211-226.
- Milner, B., & Petrides, M. (1984). Behavioural effects of frontal-lobe lesions in man. Trends in Neuroscience, 7, 403-407.
- Mitrushina, M. & Satz, P. (1989). Differential decline of specific memory components in normal aging. Brain Dysfunction, 2, 330-335.
- Mittenberg, W., Seidenberg, M., O'Leary, D. S., & DiGiulio, D. V. (1989). Changes in cerebral functioning associated with normal aging. Journal of Clinical and Experimental Neuropsychology, 11, 918-932.
- Moscovitch, M. (1982). Multiple dissociations of function in amnesia. In L. S. Cermak (Ed.), Human memory and amnesia (pp. 337-370). Hillsdale, New Jersey: Lawrence Erlbaum.
- Moscovitch, M. (1989). Confabulation and the frontal systems: Strategic versus associative retrieval in neuropsychological theories of memory. In H. L. Roediger III & F. I. M. Craik (Eds.), Varieties of memory and consciousness: Essays in honour of Endel Tulving (pp. 133-160). Hillsdale, New Jersey: Lawrence Erlbaum.

- Moscovitch, M., & Winocur, G. (1983). Contextual cues and release from proactive inhibition in young and old people. Canadian Journal of Psychology, 37, 331-344.
- Novoa, O. P., & Ardila, A. (1987). Linguistic abilities in patients with prefrontal damage. Brain and Language, 30, 206-225.
- 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 (2nd ed., pp. 463-473). New York: Van Nostrand Reinhold.
- Osterrieth, P. A. (1944). Le test de copie d'une figure complex: Contribution à l'étude de la perception et de la mémoire. Archives de Psychologie, 30, 286-356.
- Parkin, A. J., Leng, N. R. C., Stanhope, N., & Smith, A. P. (1988). Memory impairment following ruptured aneurysm of the anterior communicating artery. Brain and Cognition, 7, 231-243.
- Parkin, A. J., & Walter, B. M. (1991). Aging, short-term memory, and frontal dysfunction. Psychobiology, 19, 175-179.
- Pedhazur, E. J. (1982). Multiple regression in behavioral research (2nd ed.). New York: Holt, Rinehart, & Winston.
- Peterson, L. R., & Peterson, M. J. (1959). Short-term retention of individual verbal items. Journal of Experimental Psychology, 58, 193-198.
- Petrides, M. (1985). Deficits on conditional associative-learning tasks after frontal- and temporal-lobe lesions in man. Neuropsychologia, 23, 601-614.
- Petrides, M. (1990). Nonspatial conditional learning impaired in patients with unilateral frontal but not unilateral temporal lobe excisions. Neuropsychologia, 28, 137-149.
- Poon, L. W. (1985). Differences in human memory with aging: Nature, causes, and clinical implications. In J. E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging (pp. 427-461). New York: Van Nostrand Reinhold.
- Prigatano, G. P., & Pribram, K. H. (1982). Perception and memory of facial affect following brain injury. Perceptual and Motor Skills, 54, 859-869.

- Printz, P. N., Dustman, R. E., & Emmerson, R. (1990). Electrophysiology and aging. In J. E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging (3rd ed., pp. 135-149). San Diego: Academic Press.
- Regard, M. (1981). Cognitive rigidity and flexibility: A neuropsychological study. Unpublished doctoral dissertation, University of Victoria, British Columbia.
- Rey, A. (1941). L'examen psychologique dans les cas d'encéphalopathie traumatique. Archives de Psychologie, 28, 286-340.
- Rinn, W. E. (1988). Mental decline in normal aging: A review. Journal of Geriatric Psychiatry and Neurology, 1, 144-158.
- Ryan, J. J., Paolo, A. M., & Brungardt, T. M. (1990). Standardization of the Wechsler Adult Intelligence Scale-Revised for persons 75 years and older. Psychological Assessment, 2, 404-411.
- Salthouse, T. A. (1980). Age and memory: Strategies for localizing the loss. 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. 47-65). Hillsdale, New Jersey: Lawrence Erlbaum.
- Salthouse, T. A. (1985). Speed of behavior and its implications for cognition. In J. E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging (2nd ed., pp. 400-426). New York: Van Nostrand Reinhold.
- Sandson, J., & Albert, M. L. (1984). Varieties of perseveration. Neuropsychologia, 22, 733-744.
- Schacter, D. L., Harbluk, J. L., & McLachlan, D. R. (1984). Retrieval without recollection: An experimental analysis of source amnesia. Journal of Verbal Learning and Verbal Behavior, 23, 593-611.
- Schaie, K. W. (1990). Intellectual development in adulthood. In J. E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging (3rd ed., pp. 291-309). San Diego: Academic.
- Schiebel, A. B. (1981). The gerohistology of the aging human forebrain: Some structuro-functional considerations. In S. J. Enna, T. Samorajski, & B. Beer (Eds.), Brain neurotransmitters and receptors in aging and age-related disorders (Aging, Vol. 17; pp. 31-41). New York: Raven.

- 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.
- Ska, B., & Nespoulous, J. L. (1988). Encoding strategies and recall performance of a complex figure by normal elderly subjects. Canadian Journal on Aging, 7, 408-416.
- Smith, A. D. (1980). Age differences in encoding, storage, and retrieval. 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. 23-45). Hillsdale, New Jersey: Lawrence Erlbaum.
- Smith, D. B. D., Thompson, L. W., & Michalewski, H. J. (1980). Averaged evoked potential research in adult aging: Status and prospects. In L. W. Poon (Ed.), Aging in the 1980s (pp. 135-154). Washington, D. C.: American Psychological Association.
- Spreen, O., & Strauss, E. (1991). A compendium of neuropsychological tests. New York: Oxford.
- Squire, L. R. (1982). Comparisons between forms of amnesia: Some deficits are unique to Korsakoff's syndrome. Journal of Experimental Psychology: Learning, Memory, and Cognition, 8, 560-571.
- Squire, L. R. (1987). Memory and brain. New York: Oxford University Press.
- Statistics Canada (1990). A portrait of seniors in Canada (catalogue no. 89-519). Ottawa: Supply and Services Canada.
- Statistics Canada (1992). Profile of census divisions and subdivisions in British Columbia, part A (1991 Census of Canada, catalogue no. 95-384). Ottawa: Supply and Services Canada.
- Statistics Canada (1993). Educational attainment and school attendance (1991 Census of Canada, catalogue no. 93-328). Ottawa: Supply and Services Canada.
- Stroop, J. R. (1935). Studies of interference in serial verbal reaction. Journal of Experimental Psychology, 18, 643-662.
- Stuss, D. T., & Benson, K. F. (1986). The frontal lobes. New York: Raven Press.

- Stuss, D. T., Kaplan, E. F., Benson, D. F., Weir, W. S., Chiulli, S., & Sarazin, F. F. (1982). Evidence for the involvement of orbitofrontal cortex in memory functions: An interference effect. Journal of Comparative and Physiological Psychology, 96, 913-925.
- Tabachnick, B. G., & Fidell, L. S. (1989). Using multivariate statistics (2nd ed.). New York: Harper Collins.
- Tamkin, A. S., & Jacobsen, R. (1984). Age-related norms for the Hooper Visual Organization Test. Journal of Clinical Psychology, 40, 1459-1463.
- Terry, R. D., DeTeresa, R., & Hansen, L. A. (1987). Neocortical cell counts in normal human adult aging. Annals of Neurology, 21, 530-539.
- Tulving, E. (1962). Subjective organization in free recall of "unrelated" words. Psychological Review, 69, 344-354.
- Van Gorp, W. G., & Mahler, M. (1990). Subcortical features of normal aging. In J. L. Cummings (Ed.), Subcortical dementia (pp. 231-250). New York: Oxford.
- Veroff, A. E. (1980). The neuropsychology of aging: Qualitative analysis of visual reproductions. Psychological Research, 41, 259-268.
- Villki, J. (1989). Perseveration in memory for figures after frontal lobe lesion. Neuropsychologia, 27, 1101-1104.
- Warren, L. R., Butler, R. W., Katholi, C. R., & Halsey, J. H. (1985). Age differences in cerebral blood flow during rest and during mental activation measurements with and without monetary incentive. Journal of Gerontology, 40, 53-59.
- Wechsler, D. (1981). The Wechsler Adult Intelligence Scale-Revised. New York: Psychological Corporation.
- Wentworth-Rohr, I., Mackintosh, R. M., & Fialkoff, B. S. (1974). The relationship of Hooper VOT score to sex, education, intelligence and age. Journal of Clinical Psychology, 30, 73-75.
- Whelihan, W. M., & Leshner, E. L. (1985). Neuropsychological changes in frontal functions with aging. Developmental Neuropsychology, 1, 371-380.
- Wickens, D. D. (1970). Encoding categories of words: An empirical approach to meaning. Psychological Review, 77, 1-15.

- Yesavage, J. A., Brink, T. L., Rose, T. L., Lum, O., Huang, V., Adey, M., & Leirer, V. O. (1983). Development and validation of a geriatric depression screening scale: A preliminary report. Journal of Psychiatric Research, 17, 37-49.
- Zatorre, R. J., & McEntee, W. J. (1983). Semantic encoding deficits in a case of traumatic amnesia. Brain and Cognition, 2, 331-345.
- Zatz, L. M., Jernigan, T. L., & Ahumada, A. J. (1982). Changes on computed cranial tomography with aging: Intracranial fluid volume. American Journal of Neuroradiology, 3, 1-11.

APPENDIX

Information and Screening Form

Subject number: _____ Date of testing: _____
 Date of birth: _____ Age: _____
 Sex: M F _____ Handedness: L R _____
 Education: _____ Occupation: _____

Do you now or have you ever had any of the following? (Exclusion criteria are listed in parentheses.)

- hearing or visual problems (if interfere with ability to participate in study)
- cancer (if diagnosed within the last 3 years and if not skin cancer)
- brain tumor (any)
- heart disease or heart attack (if there were changes in memory, language, or problems solving 24 hours after the heart attack)
- head injury (with loss of consciousness greater than five minutes)
- loss of consciousness for any other reason (greater than one hour)
- stroke or transient ischemic attack (diagnosed)
- encephalitis or meningitis (diagnosed)
- carbon monoxide poisoning (diagnosed)
- Alzheimer's disease or other dementia (diagnosed)
- Huntington's disease (diagnosed)
- Parkinson's disease (diagnosed)
- Multiple sclerosis (diagnosed)
- seizures or epilepsy (any other than febrile seizures)
- treatment by a neurologist or neurosurgeon
- brain surgery (any)
- special brain tests such as EEG, CAT, MRI
- depression (if ever given electroconvulsive therapy)
- hospitalization for any other reason
- complications or problems at birth
- learning disabilities in school (diagnosed, or attended special classes)
- unusual memory complaint

How would you rate your present health: excellent, good, fair, or poor?

How much alcohol do you drink? (more than 3 drinks daily)

Are you currently taking any medications?

Do you receive any outside help for household or self-care needs?

How do you spend your days?

VITA

Surname: Troyer

Given Names: Angela Kay

Place of Birth: Toledo, Ohio

Date of Birth: August 14, 1966

Educational Institutions Attended:

| | |
|------------------------|--------------|
| University of Victoria | 1988 to 1994 |
| Bethel College | 1984 to 1988 |

Degrees Awarded:

| | | |
|------|------------------------|------|
| M.A. | University of Victoria | 1990 |
| B.A. | Bethel College | 1988 |

Honors and Awards:

| | |
|--|-----------|
| Arthur Lester Benton Bursary | 1993 |
| Graduate Teaching Award | 1990 |
| University of Victoria Fellowship | 1988-1993 |
| B.A. awarded <i>summa cum laude</i> | 1988 |
| American Association for the Advancement of Sciences Outstanding Student Presentation Award | 1988 |
| Bethel College Senior Fellowship in Psychology | 1987-1988 |
| Bethel College Dean's Scholarship | 1984-1988 |

Publications:

Troyer, A. K., Graves, R. E., & Cullum, C. M. (in press). Executive functioning as a mediator of the relationship between age and episodic memory in healthy aging. Aging and Cognition.

Troyer, A. K., Cullum, C. M., Smernoff, E. N., & Kozora, E. (in press). Age effects on Block Design: Qualitative performance features and extended time effects. Neuropsychology.

Poindron P., Rempel, N., Troyer, A., & Krehbiel D. (1989). Genital stimulation facilitates maternal behavior in estrous ewes. Hormones and Behavior, 23, 305-316.

PARTIAL COPYRIGHT LICENSE

I hereby grant the right to lend my dissertation to users of the University of Victoria Library, and to make single copies only for such users or in response to a request from the Library of any other university, or similar institution, on its behalf or for one of its users. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by me or a member of the University designated by me. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Title of Dissertation: The Relationship Between Executive Functioning And Memory Performance In Healthy Older Adults

Author:

Angela Kay Troyer

November 8, 1993