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RISK FACTORS OF COGNITIVE DECLINE IN A COMMUNITY-BASED SAMPLE OF OLDER ADULTS

By

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ABSTRACT

RISK FACTORS OF COGNITIVE DECLINE IN A COMMUNITY-BASED SAMPLE OF OLDER ADULTS

By

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Most cross-sectional studies of human aging find that the majority of cognitive abilities continuously decline after the third decade of life. Research has been particularly consistent in showing decrements in the areas of speed of processing and higher-order reasoning. This thesis investigated the hypothesis that individual differences among older adults, including premorbid intelligence, level of education, type of occupation, health status, and gender, moderate age-related cognitive decline in the areas of speed of processing and executive functioning. The sample included 203 community-dwelling older adults between the ages of 54 and 87 (M=69.11 years). All variables were measured using standard neuropsychological tests of performance and a short demographic questionnaire. Multiple regression analyses were used to determine the moderating effect of each demographic variable on both the relationship between age and executive functioning and the relationship between age and speed of processing. Results indicated that age was significantly correlated to a decline in executive functioning (r=.38; p<.01) and speed of processing (r=-.437, p<.01). However, none of the demographic variables were identified as significant moderators of either relationship. These results are discussed in light of their practical, theoretical, and methodological implications and in the context of suggestions for future research.

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INTRODUCTION

Cognitive changes associated with older adulthood have long been the focus of substantial research in the fields of psychology, human development, neuropsychology and medicine. As early as the 1920's, psychological research on aging and cognition was producing a wealth of interesting, if not surprising, results on the abilities of adults relative to their younger cohorts. In 1928, Hollingworth published data from one of the first studies showing that the performance of adults aged 35 to 40 on a symbol substitution test was 16% lower than scores of individuals in their late teens (Hollingworth, 1928). This controversial finding created an emergence of empirical work in the psychological literature and over the course of the next 20 years, researchers from varied disciplines studied age-related changes in the scores of different types of intelligence tests and replicated the findings of Hollingworth (Lezac, 1987). However, despite years of study and accumulated evidence of the effects of aging, it was not until 1949. when the popular Wechsler-Bellevue Intelligence Scale incorporated age differentials into its IQ score norms, that age was accepted as a significant variable in the study of cognition (Lezac, 1987).

Since 1949, the effects of aging on human potential have taken an even greater importance in the United States and other parts of the world as the population of individuals over the age of 65 has increased at a dramatic and unprecedented rate. According to some estimates, by the year 2000, one American in seven will be over the age of 65 and as early as 2025, the proportion of these individuals will become 1 in 5 (Tranel. Benton, & Olson, 1997). This age group is the fastest growing segment of the population as advances in the field of medicine, as well as an improved standard of living, continue to prolong the life expectancy of men and women into the 8^{th}, 9^{th} and 10^{th} decades. This trend is bound to have serious economic, political, and social implications (Powell & Whitla, 1994), making research in this area of even greater importance.

It is not surprising that the product of over 70 years of empirical research on adult cognition has shown that age has a profound effect on virtually all biological, psychological, and social functioning, including cognition. Many studies, like that of Hollingworth, have shown age-related cognitive decline in numerous abilities using a variety of measures. In fact, most cross-sectional studies of human aging find that the majority of cognitive abilities continuously decline after the third decade of life (Wechsler, 1956). Research has been particularly consistent in showing decrements in the areas of speed of processing (Cerella, 1990; Hartley, 1986, 1993; Hultsch, Hertzog, & Dixon, 1990; Kail & Salthouse, 1994; Salthouse 1985a, 1992; Schaie, 1989, 1994; Van Gorp, Satz, & Mitrushina, 1990) and higher-order reasoning (Haaland et al, 1987; Daigneault, Braun, & Whitaker, 1992; Ardila & Rosselli, 1989; Whelihan & Lesher, 1985; Shimamura & Jurica, 1994; Salthouse & Mitchell, 1990; Burke, 1972; Barr & Giambra, 1990; Pierce et al, 1989). However, despite the overwhelming evidence of late-life cognitive decline, it is now known that age is associated with greater variability in performance (Christensen et al., 1994; Morse, 1993; Rabbitt, 1993). In other words, differences in performance on a variety of cognitive measures between the lowest and highest scoring individuals has been found to increase as the age group being studied increases. One important question raised by these findings is whether increasing age necessarily leads to a decrease in cognitive functions. More specifically, are there individuals who do not demonstrate cognitive decline as they age? Or, are there individuals whose decline is less than normal and who show a flatter trajectory of deterioration than their peers? Finally, since individual differences do exist, in what ways are individuals who show little or no cognitive decline different from those who decline more rapidly? Stated another way, what are the risk and protective factors of late-life cognitive decline?

The purpose of the following research protocol is to determine whether individual differences among older adults, including premorbid intelligence, level of education, type of occupation, gender, or health status, moderate age-related cognitive decline in the areas of speed of processing and executive functioning. The present work will attempt to elucidate the most important risk and protective factors associated with late-life cognitive deficits and determine the relative strength of each of these variables in predicting the rate of intellectual deterioration in a sample of community dwelling older adults.

Attempting to uncover the relationship between age and cognitive decline at the individual level has a number of important benefits and practical implications. First, instead of making broad generalizations about the way age negatively impacts cognition, we can begin to tackle the complexities of the aging experience and identify those factors which have the most direct impact on intellectual decline. Secondly, once the risk and protective factors have been identified, we can use that information to target at-risk populations and begin to explore more appropriate prevention and treatment options. Finally, identifying at-risk populations will benefit the field of gerontology as we can begin to more clearly focus our research on those factors most relevant to the aging process and each individual's quality of life.

Before describing the methodology and specific hypotheses of the present study, it is necessary to provide a brief review of the literature on the risk factors associated with cognitive decline in older individuals. In addition, since speed of processing and executive functioning will be used as measures of cognitive decline in this study, a brief introduction to the research in these areas is also needed.

Individual Differences

In a typical laboratory study of aging and cognitive decline, the performance of elderly adults on a variety of cognitive tasks is compared with that of a group of young adults. The usual findings are that the old remember less than the young and that age differences are greatest for tasks that measure speed of processing (Hertzog, 1991; Salthouse, 1985b) or executive functions (Mittenberg et al., 1989). Although these demonstrations provide valuable information about how task variables affect age differences in performance, they tell relatively little about the aging process as it relates to cognitive decline and they fail to account for the marked individual differences among older adults in the degree to which their cognition is impaired relative to young adult standards.

Aging is a developmental process and, as such, it reflects not only the biological changes that take place over the life span but also the environmental contexts in which those changes are occurring (Baltes, 1987). Researchers studying human aging from a contextualist perspective (e.g. Baltes, 1987; Schaie, 1983) have viewed developmental changes in cognition as resulting from a lifelong series of mutually causal interactions between the characteristics of the individual and the demands and supports provided by the environment. The basic proposition of contextualism is that "any particular course of individual development can be understood as the outcome of the interactions among three systems of developmental influences: age-graded, history-graded, and nonnormative" (Baltes, 1987). Age-graded factors include biological aging and variables closely associated with it. History-graded influences include changes among different cohorts (e.g. level of education) as well as period-specific events (e.g. World War II). Nonnormative influences, which are the focus of this study, include all those contextual variables that contribute to the individuality or idiosyncrasy of development. In more recent literature, these variables have usually been described as "individual difference variables" or "psychosocial variables". The usefulness of the contextual perspective in the study of aging is supported by longitudinal data on intellectual change. For example, Schaie (1983) reported that, although mean performance on intellectual tasks does decline with age, individual differences in maintenance of intellectual functioning over time are predicted by a complex interaction among favorable life experiences, greater education and socioeconomic status, active engagement in social and intellectual activities, and a flexible personality style.

Adoption of a contextualist position implies that, to gain a fuller understanding of the aging process as it relates to cognitive decline, it is necessary to take into consideration the individual characteristics and life experiences which may greatly impact the level and rate of intellectual decline for any given individual. Although contextual variables have generally not been the object of study within the traditional literature, the situation appears to be changing. Although a relatively few number of studies have been conducted, previous research and theory within the contextual framework (e.g. Schaie, 1983) suggest that at least two broad categories of contextual factors are relevant to age changes in cognitive abilities: demographic and health factors, including gender, level of education, occupation, socioeconomic status, and general physical health, and psychological factors, including such things as the presence of anxiety or depression.

Risk Factors of Cognitive Decline

Although it is suspected that a number of risk factors are directly related to the development of late-life cognitive decline, there is a paucity of information with respect to the influence of demographic, health, and psychological factors on neuropsychological test performance (Boone et al., 1993; Golden, 1981; Reynolds, 1997). This seems to be the norm rather than the exception in neuropsychology. That is, research has, in large part, neglected the influence of demographic variables on neuropsychological test results. Demographic variables, such as gender, premorbid intelligence, level of education, type of occupation, socioeconomic level, and other factors, such as health status, can have an impact on the integrity of cognitive functions. Knowledge about the relative influence of these variables is critical for our understanding of the individual differences that are associated with intellectual decline in old age (Boone et al., 1993).

While there has been little research on risk and protective factors associated with the processes of *normal* aging, in recent years there have been a number of community-based epidemiological studies of dementia and associated risk factors. These studies have identified a number of psychosocial characteristics, such as low levels of education and premorbid intelligence, that are predictive of brain pathology in later life. This research, while also limited, does provide clues as to the specific demographic factors which may increase the risk for, or provide protection against, cognitive decline. The empirical findings for studies which have investigated the impact of gender, premorbid intelligence, level of education, type of occupation, and health status on cognitive changes for both normal aging and dementia are reviewed below.

Education

Community longitudinal studies using large numbers of subjects have reported an association between low educational attainment and decline in cognitive function in later life, noting that less well educated people deteriorate to a greater extent than better educated people over various follow-up periods (Colsher and Wallace, 1991; Evans et al., 1993; White et al., 1994; Farmer et al., 1995; Bornstein and Suga, 1988; Wiederholt et al., 1993). There have also been numerous investigations of educational attainment as a risk factor for dementia in Alzheimer's disease. Several population-based investigations of the prevalence of AD have reported higher rates of AD among individuals with fewer years of education (Sulkava et al., 1985; Zhang et al., 1990; Korczyn et al., 1991). Similarly, a study by Evans et al. (1993) found that the risk of disease decreased by approximately 17% for each year of education.

The results of some incidence studies, however, have been conflicting. In a community-based cohort in New York, subjects with less than eight years of education were at significantly greater risk for the development of AD during the four years of follow-up than subjects with eight or more years of education (Stern et al., 1994). In contrast, the incidence of AD in the Framingham Study (Cobb et al., 1995) and the Mayo Clinic Rochester Epidemiology Project (Beard et al., 1992) was not affected by educational attainment. Differences between these studies in the range of education in the populations studied and the methods used to assess cognition and diagnose dementia may have contributed to these opposing results.

The existence of a strong association between educational attainment and cognitive functioning is gaining more support but remains controversial. In order to explain this finding, some have suggested that individuals with lower education levels may perform more poorly because of impaired test-taking ability (Escobar et al., 1986; Kittner et al., 1986; Anthony et al., 1982). However, the interpretation that test bias is primarily responsible for the observed association between educational attainment and cognitive functioning is weakened by the accumulating evidence supporting an inverse association between educational level and the prevalence and incidence of dementia, as well as between educational attainment and the rate of cognitive decline (Colsher and Wallace, 1991).

If education does indeed reduce the risk of cognitive decline and the prevalence of dementing illnesses such as AD, a number of mechanisms may be offered to explain the link. Education might in some way protect against neurodegeneration (Schmand, 1997) or the onset of dementia might be delayed because education had improved neuronal networking so that when neurons died others could carry out similar functional tasks and thereby minimize the signs of cognitive impairment (Swaab, 1991). This "brain reserve" theory has been reviewed by Katzman (1993), who noted that education could increase brain reserve by increasing the density of neocortical synapses in the brain and delay the onset of symptoms in Alzheimer's disease by up to five years. He pointed to several studies showing that the brains of elderly rats reared in an enriched environment had increased cortical thickness and weight and increased dendritic branching and that these rats' general performance was better than that of control rats from a non-stimulating environment. Dendritic growth continues in humans well into old age (Buell et al., 1979). Therefore, previous education as well as continued mental activity may be important for older adults. Educational attainment and stimulating mental activity may help improve coping skills and strategies for solving problems, and in turn these may help offset the cognitive effects of normal aging and delay the clinical symptoms associated with Alzheimer's disease.

Premorbid Intelligence

Another factor that may influence the rate of cognitive decline and the expression of dementia in old age is premorbid intellectual ability. It has been hypothesized that, similar to level of educational attainment, premorbid intellectual ability reflects a cognitive reserve that can alter the effects of age on cognitive functioning as well as the clinical expression of dementia in Alzheimer's disease (Schmand, 1997). While the research in this area is quite sparse, there is some evidence to support the theory that a high level of premorbid ability may indicate more cognitive resources, which allow for greater compensatory skills in response to advancing decline. It is also possible that premorbid experience directly influences brain function at the neuronal level. Increasing levels of mental stimulation during life can lead to alterations in brain physiology, such as production of greater synaptic interconnectivity among neurons (Greenough et al., 1981; Diamond, 1990). A high level of premorbid intellectual function may reflect greater availability or efficiency of functional brain systems that are recruited when the performance of a task requires greater mental effort.

One of the first studies to examine the effect of premorbid intelligence on cognitive decline was a five-year longitudinal study of initially normal 75-85 year-old World War II veterans (Plassman et al., 1995). They found that cognitive status at the beginning of the study was the best predictor of subsequent development of AD symptoms. Other investigations have found similar results, including the well-publicized longitudinal investigation of 678 elderly Catholic nuns. Using linguistic measures derived from essays written by sisters at the time they took their final vows (around age 22), Snowdon et al. (1996) found that sisters with poor linguistic ability were up to 31 times more likely to be cognitively and functionally impaired in old age. Verbal ability, especially 'idea density', was more strongly related to cognitive functioning than other demographics, such as educational attainment, some sixty years later. Idea density was even related to the number of neurofibrillar tangles in various regions of the brain.

More recent studies have also supported these earlier investigations, though more research is needed to confirm the findings. Schmand et al. (1997) conducted a four year longitudinal study of over 2,000 elderly subjects and found that premorbid IQ was the second strongest predictor, after age, of incident dementia. Another study by Alexander et al. (1994) investigated the relation between estimates of premorbid intellectual function and cerebral glucose metabolism in patients with Alzheimer's disease to test the effect of differing levels of premorbid ability on neurophysiological dysfunction. Using positron emission tomography (PET), the authors found that premorbid intellectual abilities were predictive of cerebral metabolism and the neurophysiological heterogeneity observed in AD. Overall, the few studies to investigate the relation between intelligence and later cognitive functioning lend some support for the theory that premorbid cognitive ability plays a role in determining the level of cognitive reserve in old age.

Gender

The impact of gender on neuropsychological measures has been studied for many years and the typical finding is that women outperform men on measures of verbal ability while men perform better than women on tasks that involve visuospatial reasoning and speed of processing (Wiederholt, 1993). However, such differences do not provide information relating to the nature of cognitive deterioration associated with gender. In fact, only recently has the study of gender differences been incorporated into the investigation of risk factors of cognitive decline.

The influence of gender on intellectual stability remains unclear as the research is not only limited, but has also produced mixed results. While some studies have shown a relationship between female gender and greater cognitive deterioration and occurrence of AD (Launer et al., 1999; Sulkava et al., 1985; Rocca et al., 1990; Zhang et al., 1990), other investigations have challenged these findings (Fratiglioni et al., 1991; Bowler et al., 1998; Letenneur et al., 1994; Paykel et al., 1994). In fact, there is evidence that men with AD may be at disproportionate risk for death compared to female cases and that the apparently higher prevalence of AD among women may simply reflect this differential mortality (Perls et al., 1993; Corder et al., 1995).

Most studies that have investigated the association between cognitive decline and gender have done so in an attempt to predict the development of some form of dementia, and thus little research has been devoted to the impact of gender as a risk or protective factor of normal aging. One study by Wiederholt et al. (1993) examined the effects of gender on selected neuropsychological tests in a community cohort of normal elderly and found that cognitive deterioration was significantly greater for men than for women on a number of intellectual measures. However, another study conducted by Lowe and Reynolds (1999) found that gender differences had no influence on level of cognitive ability in their sample of healthy elderly individuals. Thus, it is not currently known whether gender has any influence on the rate of cognitive decline associated with advancing age.

Health Status

While there is great speculation that health status is related to the deterioration of cognitive abilities in the elderly, there has been little investigation into the strength of this variable in predicting the level of intellectual decline with advancing age, though this has recently begun to change (Abate et al., 1998). Among the few studies examining the relationship between health status and intellectual performance during adulthood is the work of Perlmutter and Nyquist (1990). Using forward and backward digit span as a measures of memory, they found that education together with gender explained less than 1% of the variance in memory performance of subjects aged 20 to 50 but explained a statistically significant 12% of the variance in performance of subjects aged 60 and over. More interesting, however, was the finding that when measures of physical health were added to the regression equation, the explained variance in memory performance showed a non-significant increase to 7% for the group aged 20 to 50 but a significant increase to 27% for the group aged 60 and over. The authors of this study hypothesize that health factors have a moderating effect on other variables that may impact cognition and should therefore be included in any investigation of risk factors associated with cognitive decline among older adults.

This hypothesis was recently confirmed by at least one study by Arbuckle et al. (1992). The researchers investigated the impact of demographic factors on cognition, including age, education, social support, etc., and found that many of these variables, including health status, contributed to intellectual performance only indirectly through their relationship with current intelligence. While there was no a priori theoretical reason for predicting that health status would be related to cognition through general intelligence, the authors mention that in hindsight it seems obvious that poor health could have a generalized debilitating effects on all cognitive abilities. Therefore, it is important that health status be measured when possible because, although the research is in its infancy, it is clear that such a variable has the potential to greatly impact the stability of cognitive functions throughout adulthood.

Occupation

The psychological literature reflects few studies of the association between occupational attainment and cognitive decline and those studies that have been conducted show substantial variation (Evans et al., 1997). Some investigations have shown that lifetime occupation is a significant predictor of Alzheimer's disease, independent of its association with education (Evans et al., 1997; Bonaiuto et al., 1995; Schmand et al., 1997). In addition, individuals with both low educational and low occupational attainment have been shown to be at increased risk of AD (Stern et al., 1994). In one study, Stern and colleagues followed a cohort of non-demented elderly individuals for 1-4 years. At the initial visit, each subject's primary occupation was classified according to the US census categories. Based upon these categories, subjects were grouped into low (unskilled/semiskilled, skilled trade or craft and clerical/office worker) and high (manager business/government and professional/technical) occupational levels. Subjects with lower occupational attainment were at more than twice the risk of developing AD and the increased risk for subjects with both low educational and occupational attainment approached threefold. In a later study of occupation and regional cerebral blood flow (rCBF) of the parietal lobe, Stern et al. (1995) demonstrated that, among patients matched for clinical disease severity, those who had occupations involving more substantive complexity, more interpersonal skills, and higher physical demands, showed greater cognitive reserve against the clinical expression of AD. These and other investigators have hypothesized that lifetime occupation could supply a reserve that allows individuals to cope longer before intellectual deterioration is experienced. This reserve could be an acquired set of skills or repertoires or the result of an increased synaptic density developed on the basis of long-term stimulation. It has even been speculated that lifetime occupation is more important than years of education in protecting against cognitive decline given the relatively brief period of life spent in school compared to time spent on the job (Stern, 1994).

Despite the findings from these studies, however, other researchers have not been as successful in demonstrating a relationship between occupation and cognitive reserve. In fact, a number of investigations have reported no significant association between the two variables (Brayne and Calloway, 1990; O'Connor et al., 1991; Bowler, 1998). The study by Bowler and colleagues (1998) investigated the impact of occupation on the development of Alzheimer's disease and found that the age of onset and the rate of progression of the disease were not significantly influenced by lifetime occupation. Similarly, an analysis of data from the Kungsholmen study (Fratiglioni et al., 1991) and a prevalence study among African Americans (Callahan et al., 1996) also suggested no association. More research is needed to determine the relative influence, if any, of occupational attainment on cognitive functioning in older adults.

Cognitive Decline Among the Elderly

As mentioned previously, most cross-sectional studies of human aging find that the majority of cognitive abilities continuously decline after the third decade of life (Wechsler, 1956). Research has been particularly consistent in showing decrements in the areas of speed of processing (Cerella, 1990; Hartley, 1986, 1993; Hultsch, Hertzog, & Dixon, 1990; Kail & Salthouse, 1994; Salthouse 1985, 1992; Schaie, 1989, 1994; Van Gorp, Satz, & Mitrushina, 1990) and higher-order reasoning/executive functioning (Haaland et al, 1987; Daigneault, Braun, & Whitaker, 1992; Ardila & Rosselli, 1989; Whelihan & Lesher, 1985; Shimamura & Jurica, 1994; Salthouse & Mitchell, 1990; Burke, 1972; Barr & Giambra, 1990; Pierce et al, 1989). Since these processes are known to decline with age, both speed of processing and higher-order reasoning will be measured in the present study in order to provide an index of intellectual functioning and to test the hypothesis that demographic variables, such as gender, premorbid intelligence, level of education, type of occupation, and health status, impact their integrity as individuals grow older. It is thus necessary to provide a brief summary of the literature on the effects of age on executive functioning and speed of processing before describing the methodology in more detail.

Age-Related Decline in Executive Functioning

Research over the last two decades has shown that normal aging is accompanied by neurological changes in the brain (Moscovitch & Winocur, 1992). Often, these changes are both structural and functional and are likely to influence cognitive functioning during the later part of life. One finding in particular, which has had great impact on the field, is that normal aging is often connected with frontal lobe and prefrontal lobe changes (Albert & Kaplan, 1980). Since this was first discovered in 1980, there has been a great deal of evidence suggesting that there is a selective, age-related decline in performance on neuropsychological tests which measure executive functioning of the frontal lobe. Interestingly, a number of studies have shown that older adults perform poorly on measures of frontal lobe function when compared to younger adults, while performing similarly to younger adults on most tasks not related to frontal lobe function (Ardila & Rosselli, 1989). These findings have led researchers and theorists to suggest that the cognitive processes associated with the frontal lobes are among the first to decline with age. Although a decrease in frontal lobe function has been shown to occur with old age, it most likely does not affect all individuals equally. However, the extent to which the decrease in executive function can be predicted by individual premorbid variables is not yet known.

The idea that executive functions are associated with the frontal lobe of the brain is perhaps an old one, stemming from case studies involving patients with frontal damage. Undoubtedly, the most popular such account is that of Phineas Gage, a now famous subject who suffered damage to the frontal region of his brain when a steel pipe was shot through his head. Phineas Gage survived the accident, however, major changes in his personality and behavior left him a different person. Perhaps the most significant and most noteworthy change in Gage's life following the injury was his inability to take control and organize his life in a meaningful way.

Clinical reports of the behavior of individuals sustaining frontal lobe damage, like that of Phineas Gage, have produced a wealth of descriptive information regarding the nature of functioning of that area of the brain. Deficits of attention, memory, and planning have been well documented characteristics of frontal lobe damage. These "higher order" capacities associated with the frontal lobe were named the "central executive" by Baddeley and Hitch in 1974 (Baddeley, 1998) and have since been referred to as "executive functions".

The executive functions of the brain have been described in many ways. Perhaps one of the most comprehensive and understandable models is that given by Muriel Lezak. Lezak (1993) describes the functions of the central executive as a four-part classification schema which includes volition, planning, purposive action, and performance effectiveness. Volition includes the ability to be aware of one's self, the surrounding world, and one's level of motivation. The act of planning involves being able to "conceptualize change (look ahead), be objective, conceive of alternatives and make choices, develop a plan conceptually, and sustain attention" (Lezak, 1993). Purposive action is described as self-regulation and productivity. Finally, executive functions are thought to involve performance effectiveness which is, in other words, maintaining quality control over one's actions. Impairment or loss of these functions can cause a person to loose the ability to maintain an independent, constructive, and socially productive life, even when other cognitive abilities are intact.

These higher order abilities have been the focus of an enormous amount of empirical work over the years and much has been learned about these processes. Support for an age-related decline in executive functioning comes from extensive evidence from both biological and anatomical research as well as recent neuropsychological findings.

Anatomical and Biological Evidence

Structural Changes of the Aging Brain.

Anatomical and biological studies have investigated the aging brain from multiple perspectives, which range from the measurement of the gross volume of various regions to the neurochemistry and synaptic density. Numerous researchers have found evidence suggesting a significant reduction of brain mass in persons over the age of 70 (Haug & Eggers, 1991). This reduction in volume of the entire brain has been estimated by researchers to be approximately 6% when compared to brain mass of young adults. More interesting, however, is that this reduction is not uniform but rather varies by region. While the reduction in volume of the temporal, parietal, and occipital cortices of individuals over 70 is estimated at 1%, the reduction of the frontal cortex in the same individuals, is estimated to be between 10-15% (Haug & Eggers, 1991). Haug and Eggers have shown that this reduction of brain volume occurs because of the reduction of neuronal mass, and not actual loss of cells. This "shrinkage" of neurons in the frontal cortex appears to more severe than in other areas of the brain. These researchers also reported that below the age of 45, there is not much evidence of any cell deterioration. However, noticeable levels of neuronal shrinkage were seen in subjects who were 50 years of age, and the reduction of cell mass is greatly pronounced in those 65 years of age and older.

Consistent with this body of research is the finding that there may be a reduction in the number of neuronal synapses in the frontal region of aging adults. A small study of four individuals, aged 74-90 years, found that there was a significant reduction of synaptic density in certain areas of the frontal lobe (Huttenlocher, 1997). This reduction of the number of synapses could account for some of the neuronal shrinkage found in earlier studies, however, due to the small sample size, more research in this area is necessary before any specific conclusions can be drawn.

The reduction of cortical volume that has been observed with advancing age is also accompanied by an increase in the number of pathological structures present in the brain. For example, the existence of senile plaques in the brains of older adults has been well documented. Evidence from non-human (primate) research has shown that the distribution of plaques in the brain is not uniform, but again, varies by region. Greater numbers of these plaques have been revealed in the prefrontal cortex than in other areas of the brain (Struble, et al, 1985). Plaques in other areas of the brain have been associated with Alzheimer's Disease. Although the effect of plaques on brain tissue is not fully understood, it is interesting to note that they seem to have a greater affinity for frontal tissue.

All of the above findings support the hypothesis that the frontal cortex is more sensitive to the effects of aging than other areas of the brain. Research has demonstrated accelerated loss of neuronal volume, possible reduction of synaptic density, greater number of plaques, and changes in the neurochemistry of the frontal regions of the aging brain. Although the implications of these findings are not completely understood, it is clear that as we age, there are a number of biological changes that take place in the brain which may have an impact on cognitive functioning.

Functional Changes in the Aging Brain.

Investigations of the functional changes of the aging brain have incorporated two kinds of neuroimaging techniques, namely the Xenon method and positron emission tomography (PET). Both are used to measure cerebral blood flow and oxygen use in the brain, but PET has the added capability of measuring the cerebral metabolism of glucose. Unfortunately, according to Gur and colleagues (1987), these two methods have not always provided concordant results with regard to the effects of increasing age. Studies incorporating the Xenon and PET methods have in general found decreases in oxygen use associated with age, while PET studies do not typically find significant age-related differences in glucose metabolism (Gur et al, 1987).

Studies of brain function using PET and Xenon have provided evidence that increases in age are associated with a decline in cerebral blood flow in certain areas of the brain. This age-related reduction in blood flow has been estimated to exceed 27% in some regions (Melamed et al, 1980). Interestingly, whereas reduction in cerebral blood flow has been observed in the entire cortex, there is evidence to suggest that levels of decline are specific to different regions of the brain. In young and middle-aged individuals, a pattern of "hyper-frontality" is often observed (Gur et al, 1987). Hyper-frontality is characterized by a greater amount of blood flow in the frontal portions of the brain. However, in older individuals, the opposite is true – a state of "hypo-frontality" is often seen. This reduction of cerebral blood flow in the frontal region may have a negative effect on executive functioning in old age.

In addition to examining the rate of cerebral blood flow while an individual is at rest as in the above mentioned studies, researchers have also investigated cerebral blood flow while individuals perform various cognitive tasks. These tasks include things like solving mathematical problems, verbal analogies, and perception activities (Gur et al, 1987). Interestingly, these studies have not demonstrated consistent declines in blood flow in older adults who are actively performing cognitive tasks, but have found declines in the frontal regions while individuals are at rest (Gur et al, 1987). Unfortunately, these findings are difficult to interpret in light of the limited literature available on these relatively new investigative techniques.

The evidence presented in this section suggests that there are both structural and functional changes of the cerebral cortex associated with increasing age. Research has shown that these changes involving the aging brain do have a fairly high degree of regional specificity. In support of the frontal lobe hypothesis, it appears that the frontal cortex is one of those regions most affected by the aging process.

Neuropsychological Evidence.

The link between age and frontal lobe dysfunction has been demonstrated not only by biological and anatomical research, but also in studies involving cognitive performance. These studies have often pointed to the similarities between the elderly and those with frontal lobe brain damage (Mittenberg et al., 1989). In fact, the researchers who developed the frontal lobe hypothesis (Albert & Kaplan, 1980) did so after noting that their subjects illustrated age-related differences in neuropsychological performance and appeared similar to those with frontal lobe damage.

Several investigations involving comparisons of neuropsychological test performance of healthy young and older adults have provided additional support for Albert and Kaplan's frontal hypothesis. Among the most widely used measures of executive functioning are the Stroop Color-Naming Task and the Wisconsin Card Sorting Test (WCST). Both of these measures have been valuable tools in the assessment of the aging brain and its relationship to frontal lobe dysfunction.

Stroop Color-Naming Task

Research incorporating the Stroop Color-Naming Task has provided a number of findings related to the effects of increasing age and executive functioning. In the Stroop Task, an individual is asked to perform a number of reading tasks of both word and color. During the word-reading portion of the test, subjects are asked to read a series of color names printed in black ink as quickly as possible. The individual is then asked to name the color of a series of colored x's. The naming of the color is typically slower than the previous reading of words task. Finally, in the color-word naming portion, the individual is asked to name the color of a series of words printed in an incongruent color. For example, the word 'red' would be printed in blue ink. The naming of colors in this condition is generally slower than the previous tasks.

The effects of increasing age on this task have been well documented, with older adults showing significantly more slowing during the color-word interaction portion of the test (Cohn et al, 1984). These age-related differences begin to appear in individuals 60 and 70 years old and continue to increase into old age. The Stroop effect is thus consistent with the frontal lobe hypothesis.

In addition to the age-related Stroop effect, a number of variables have been shown to interact with the effects of increasing age, including health status, education, and the spatial location of the color and word information. The interaction between health status and age suggest that there is an accelerated increase of the Stroop effect with age for individuals with even relatively minor health problems. In addition, higher levels of education have been found to provide some protection against the cognitive slowing seen with aging (Houx et al, 1993).

Over the years, a number of theoretical explanations of the Stroop effect have been proposed and tested in relation to the effects of increasing age. The Stoop effect appears to reflect the difficulty of inhibitory responses on the brain to process relevant and irrelevant information (Cohen et al, 1990) and has been shown to be sensitive to frontal lobe damage. Functional brain imaging using positron emission tomography (PET) has shown that a number of frontal lobe brain structures are active during the Stroop task, validating the fact that it is, in fact, a good measure of frontal lobe ability (Bench et al, 1993).

Wisconsin Card Sorting Test (WCST)

Age group differences in performance on the Wisconsin Card Sorting Task have also been shown to be consistent with the frontal lobe hypothesis. The WCST requires the subject to sort cards in a number of different ways according to either color, number or symbol. The individual receives the cards in consecutive order and must deduce from the yes/no feedback of the examiner how to complete the task. After correctly sorting ten cards in a row, the principle is shifted and the subjects must be able to adjust their strategy in order to meet the changing demands of the examiner. Thus, the test involves higher order cognitive abilities including planning, reasoning and flexibility.

The Wisconsin Card Sorting Task has also been found to be particularly sensitive to frontal lobe damage (Nelson, 1976). Age associated decline of WCST performance has been shown in many studies. In one such study, Isingrini (1997) reported that significant age differences in favor of the young were found in adults ranging in age from 70 to 99 years of age. Thus, it appears that the age-related differences associated with this task result from at least some degree of frontal lobe dysfunction in older adults.

As illustrated above, many studies have shown that changes in the aging brain do not occur in a uniform manner, but rather vary by region. According to recent studies, it seems that the frontal lobe is a primary target for many of these changes which include neuronal shrinkage, reduction of mass, neurochemical changes, increases in pathological structures, and decreased cerebral blood flow. Indeed, the research has shown that changes in the frontal region of the aging brain are some of the most dramatic.

Although the effect of these changes is not fully understood, researchers have associated the above findings with the cognitive decline often seen in old age. A great deal of evidence from neuropsychological instruments which test frontal lobe functioning has been overwhelmingly in favor of the frontal lobe hypothesis. The two examples that were illustrated here, the Stroop Color-Naming Task, and the Wisconsin Card Sorting Task, have shown a great deal of age-related decline in executive functioning. In fact, the decline has been so remarkable, that many researchers have made a theoretical connection between the performance of the elderly and those with frontal lobe damage.

Age-Related Decline in Speed of Processing

Slowing with age is often considered one of the best documented and least controversial behavioral phenomena of aging (Birren and Fisher, 1995). Cognitive aging researchers generally agree that performance on many information-processing tasks which assess cognitive or perceptual processes is slowed with increased age (Hertzog, 1991; Salthouse, 1985). Proponents of the general slowing hypothesis of aging argue that this phenomenon is caused by a general decrease in processing rate with age (Nettelbeck and Rabbitt, 1992) and this reduction in rate is believed to affect most perceptual and cognitive processes and is thus regarded as the prime determining factor of cognitive deterioration associated with late adulthood (Salthouse, 1985; Welford, 1984). In fact, Salthouse has demonstrated that the median correlation between age and measures of speed across a wide range of behavioral activities is .45 (1985).

The evidence supporting the role of processing speed as a mediator of cognitive decline has come from cross-sectional studies in which the performance of individuals of different ages on cognitive variables was compared. During middle and late adulthood, measures of intellectual speed tend to show the largest negative age differences, followed by fluid abilities such as spatial reasoning, which in turn are followed by more knowledge-dependent measures (Salthouse, 1982). For example, the Digit Symbol Substitution subtest of the Wechsler Adult Intelligence Scale (WAIS), a typical measure of cognitive-perceptual speed, shows very pronounced age decrements, whereas the Vocabulary subtest of the WAIS, a measure of knowledge, remains stable through late adulthood (Salthouse, 1982).

Cross-sectional data reported by Hertzog (1989) and Hultsch et al. (1992) also support the importance of speed in the cognitive functioning of older adults. Hertzog investigated the influence of speed measures on other intellectual abilities in a sample of 622 adults with an age range of 43 to 89 years. Significant negative age trends were observed for all abilities that were studied, however, after controlling for speed of processing, the age trends explained only between 1-3% of the total variance in the other ability measures. Similarly, an important longitudinal study conducted by Hultsch et al. (1992) examined the changes in performance on memory, intellectual ability and information processing tasks over a three year period in 328 older adults. They found significant declines in functioning on measures of working memory, verbal fluency, and world knowledge, however, these findings were reduced or completely eliminated when they controlled for processing speed.

Salthouse and his colleagues (1991) also conducted a series of studies on the extent to which measures of perceptual speed and working memory account for age differences in complex intellectual tasks. They reported the results of three independent studies which covered an age range of 20 to 84 years. After controlling for speed, the age-related variance in cognitive tasks and working memory measures was reduced from a range of 17-31% to a range of 1-5%. In line with Hertzog's results, these findings show the significance of age-related decreases in speed of processing and demonstrate that this variable can explain a large portion of the variance associated with age-related cognitive decline.

The empirical work that has been conducted on older adults thus far has led researchers to suggest that the cognitive processes associated with speed of information processing are among the first to decline with old age. Although a definite slowing effect has been shown to characterize the cognitive functioning of older adults, it most likely does not affect all individuals equally. However, the extent to which the decrease in processing speed can be predicted by individual premorbid variables is not yet known.

Summary

Although it is suspected that a number of risk factors are directly related to the development of late-life cognitive decline, there exists little information with respect to the influence of demographic, health, and psychological factors on neuropsychological test performance (Boone et al., 1993; Golden, 1981; Reynolds, 1997). Research has, in large part, neglected the influence of demographic variables on neuropsychological test results. Demographic variables, such as gender, premorbid intelligence, level of education, type of occupation, and other factors such as health status, can have an impact on the integrity of cognitive functions. Knowledge about the relative influence of these variables is critical for our understanding of the individual differences that are associated with intellectual decline in old age (Boone et al., 1993). Therefore, the present study will significantly contribute to the literature on aging and cognition by investigating the potential impact of those demographic variables which have thus far been neglected.

Hypotheses

Based on the research reviewed above, the specific hypotheses of the present study include the expectation of the following results:

1. Confirmation of an age-related decline in measures of executive functioning and speed of processing.

2. A significant relationship will exist between age-associated cognitive decline in executive functioning and individual demographic variables. That is, fewer years of education, lower levels of occupational attainment, poor health, lower levels of premorbid intelligence, and female gender will be predictive of greater decline in executive functioning.

3. A significant relationship will exist between age-associated cognitive decline in speed of processing and individual demographic variables. That is, fewer years of education, lower levels of occupational attainment, poor health, lower levels of premorbid intelligence, and female gender will be predictive of greater decline in speed of processing.

It is expected that this sample of healthy, community-dwelling older adults will show individual variability in cognitive decline in the areas of executive functioning and speed of processing. However, it is also predicted that the level of deterioration will be predicted, at least in part, by demographic variables including premorbid intelligence, level of education, type of occupation, gender, or health status. Since the empirical work on risk and protective factors of adult cognition is at a surprisingly early stage of development, it is not known which of these factors will be the strongest in predicting the rate of cognitive decline.

METHOD

Participants

The present investigation included 234 community dwelling older adults between the ages of 54 and 87 (M = 69.11, SD = 7.86 years). Public advertisements in local newspapers and other mailings were used to solicit willing participants. Subjects who expressed an interest in the study were screened using the Mini Mental Status Exam (MMSE) as well as measures of depression, including the Beck Depression Inventory [(BDI); Beck, 1987] and the Geriatric Depression Scale [(GDS); Brink et al., 1982]. Individuals who demonstrated cognitive impairment with a score below 24 on the MMSE or those with depression as indicated by scores of 30 or higher on the Beck Depression Inventory and/or scores of 20 or higher on the Geriatric Depression Scale were excluded from the sample in order to ensure that all participants were healthy and functioning at a level consistent with normal aging. Given the exclusionary criteria used in this study, the actual sample size employed in the data analyses was 203. There were 90 males and 113 females. Subjects who participated in the study were given the opportunity to attend mood and memory training workshops at Michigan State University. Finally, informed consent was obtained from each participant prior to the completion of study procedures.

Procedures

Participants completed detailed questionnaires yielding demographic and life history information before completing a set of neuropsychological tests. The total length of testing for each individual was approximately 2 hours. The order of measures was systematically varied across participants. All testing sessions were conducted individually. The administered procedures assessed, among other things, the individual's mood, memory, executive functioning, speed of processing and general cognitive ability. For the purposes of this study, however, only data relevant to measures of executive functioning and speed of processing were analyzed and reported.

Instruments

The measures used in this investigation will include the following:

Screening Measures

Beck Depression Inventory (BDI)

The BDI (Beck, 1987) is a self-report measure consisting of 21 multiple-choice statements presented on four pages of paper. Each item is concerned with a particular aspect or symptom of depression and asks subject to rate their experience on a scale of graded severity. The approximate time required to complete the inventory is 5-10 minutes. A total score is obtained by adding the highest score circled for each of the 21 items. The total score can range from 0-63, with higher scores indicating more severe levels of depression. The instrument has classified depression severity in the following manner: 0-9 = normal range; 10-15 = mild depression; 16-19 = mild/moderate depression; 20-29 = moderate/severe depression ; 30+ = severe depression (Spreen & Strauss, 1998).

The BDI is a well researched instrument with strong psychometric properties. In addition, it has been used with a wide range of populations due to the ease of administration and scoring. In the original norming sample, Beck (1970) reported that test-retest reliability was above .90 and that change scores tended to parallel changes in depression severity for individual subjects. Reynolds and Gould (1981) have reported Spearman-Brown reliability to be .93 and internal consistency of test items to be .86.

Other authors have reported a coefficient alpha of .88 (Steer et al., 1989). Furthermore, the BDI is known to have good concurrent validity with instruments such as the MMPI Depression Scale (.75; Reynolds and Gould, 1981) and the Hamilton Rating Scale (.85; Brown et al., 1995) as well as clinical ratings of depression (.66; Schaefer et al., 1985).

Geriatric Depression Scale (GDS)

The GDS (Brink et al., 1982) is a self-report measure consisting of 30 yes/no questions pertaining to potential symptoms of depression. The instrument was designed specifically for the elderly population and is recommended for use by Spreen and Strauss (1998) due to the simplicity of administration and the fact that it contains somatic items which are more suitable for older adults than those presented on the BDI. The GDS requires subjects to read statements and answer each by circling the yes/no response which most accurately reflects their experience. Alternatively, the items can be read to subjects if there is any concern regarding their ability to read or respond using paper-and-pencil. The estimated time required for completion of the GDS is approximately 5-10 minutes. A total score is obtained on the instrument by adding the point values assigned to each response (0 or 1). The following cutoff points are used to determine level of depression: 0-9 normal range; 10-19 = mild depression; 20-30 = moderate/severe depression (Spreen and Strauss, 1998).

The psychometric properties of the GDS warrant the instrument's wide-spread use among older adult populations. Brink et al. (1982) reported that in the original norming sample, internal consistency (alpha) and split-half reliability were both .94. Retest reliability over a one-week time span has been reported to be .85 (Koenig et al., 1988). In addition, concurrent validity has been established with other self-report measures including the BDI (.73; Hyer &Blount, 1984), Hamilton Rating Scale (.83; Yesavage et al., 1986), MMPI Depression Scale (.72; Bielauskas & Lamberty, 1992), and the DMS-based Symptom Checklist for Major Depressive Disorders (.77; Bielauskas & Lamberty, 1992). Criterion validity as measured against the Research Diagnostic Criteria has been reported as .82 (Yesavage & Brink, 1983).

Mini-Mental State Exam (MMSE)

The MMSE (Folstein and McHugh, 1975) is a 30-item measure used to screen for cognitive impairment and document changes in intellectual functioning over time. The measure is easily administered and scored in a brief 5-10 minutes. The MMSE requires the examiner to ask questions and record responses given by the subject. The test consists of items that assess orientation to time and place, attention and concentration, language, constructional ability, and immediate and delayed memory recall. Each correct response is awarded one point and the total score is the number correct out of 30. Scores below 24 are considered abnormal when screening for dementia or delirium and this cut-off is recommended with most populations (Lezak, 1995).

The psychometric properties of the MMSE are well documented in the literature. Inter-rater reliability has been shown to be above .65 (Foster et al., 1988) and test-retest reliability estimates for intervals of less than two months generally fall between .80 and .95 (O'Connor et al., 1989). Most studies report that the MMSE has adequate specificity and sensitivity for detecting the presence of dementia, particularly in cases where there exists moderate to severe forms of cognitive impairment (Spreen & Strauss, 1998). The MMSE also shows modest to high correlations with measures of intelligence, memory, attention and concentration, and executive functions (Axelrod et al., 1992). In addition, Crum et al. (1993) has recently published extensive norms for the MMSE by age (18-85) and education based on probability sampling of more than 18,000 community-dwelling individuals.

Demographic Questionnaire

Information on age, gender, level of education, occupation, and health status were obtained by a self-report style demographic questionnaire. Level of education was measured in the conventional manner and based on responses to the following questions: a.) 'What is the highest grade of school you completed?' and b.) 'If you attended college, please specify how many years and what degree you obtained'. Occupational level was assessed by asking participants, 'What kind of work did you do most of your working life?'. Answers to this question were then coded according to the Eppinger Demographic Formula (Eppinger et al., 1987) in which unskilled labor = 1; semi-skilled labor = 2; not in labor force (including homemakers) = 3; skilled labor = 4; managerial/official/clerical/sales/ self-employed = 5; professional/technical/artistic = 6. Finally, health status was measured using the following questions: a.) 'How would you rate your overall health at the present time?' in which excellent = 1; good = 2; fair = 3; poor = 4 and b.) 'Do your health problems stand in the way of doing things you want to do?' in which not at all = 1; a little = 2; a great deal = 3.

Premorbid Intelligence

American New Adult Reading Test (AMNART)

The AMNART (Grober & Sliwinski, 1991) is a reading test involving 45 irregularly spelled words (e.g. naïve, subtle, facade) in which pronunciation is used to predict premorbid IQ. The subject is presented with a piece of paper containing two columns of printed words and is asked to "Look at each word carefully and say it aloud". The examiner scores each pronunciation based on the phonetic spelling guidelines provided with the instrument, which are based on the common English language dictionary. Each correct response is awarded one point and the maximum number of correct responses is 45. The estimated time needed to complete the test is approximately 2-5 minutes. Once the AMNART has been scored, a formula is used to obtain the subject's premorbid IQ score based on the number of AMNART errors and level of education. The formula used most commonly is that by Grober and Sliwinski (1991): Estimated VIQ = 118.2 - .89(AMNART errors) + .64(Years of Education).

The AMNART formula is based on a sample of 230 nonimpaired older adults (Grober & Sliwinski, 1991). The sample included approximately equal numbers of males and females with a mean age of 75 (SD = 4) and mean education of 12.5 years (SD = 3). The correlation between actual WAIS-R VIQ and estimated VIQ based on this regression formula was .76.

Speed of Processing

Symbol Digit Modalities Test (SDMT)

The SDMT (Smith, 1982) is a measure of speed of processing, complex scanning and visual tracking and allows comparison between oral and written performance (Lezak, 1995). The oral and written portions of the test each have a time-limit of 90 seconds. During the first trial, subjects are presented with a sheet of paper that has a code table displaying pairs of digits and symbols. Beneath the code table are rows of double boxes with the symbol in the top box and nothing in the bottom box. The participants are then asked to use the code table to determine which number is associated with each symbol and to write as many numbers as possible in the empty boxes in the 90 second period. During the second trial, the examiner records the numbers while they are given orally by the subject. The score obtained from this test is the number of correctly "substituted" numbers in each portion of the test with a maximum score of 110 on each. The norms for the SDMT are well established and reliability is satisfactory (Spreen & Strauss, 1998). More specifically, test-retest reliability correlations have been reported to be .80 for the written portion and .76 for the oral portion (Spreen & Strauss, 1998).

Executive Functioning

Wisconsin Card Sorting Test (WCST)

The WCST (Heaton, 1993) assesses the ability of an individual to use abstraction and to shift cognitive strategies in response to changing environmental cues (Lezak, 1995). It is widely accepted as a measure of executive function as individuals must employ strategic planning, organized searching, the ability to use environmental cues to shift cognitive sets and must act in a way that is goal-oriented (Spreen & Strauss, 1998). Subjects are asked to match a set of cards, which vary according to the number and color of different shapes, with one of 4 "key" cards. The individual is asked to complete the task in the absence of explicit matching guidelines. Instead, they must rely solely on the feedback given after each trial indicating whether they have made a correct or incorrect match. In addition, once the subject correctly matches 10 cards consecutively, the sorting principle is altered – subjects are not aware of this change and must modify their responses accordingly. A great deal of empirical work on executive functioning has been done using the WCST as both the construct validity and interrater reliability of the instrument have been well established (Lezak, 1995). In fact, interrater reliability estimates have been reported to range from .88 to .96 (Lezak, 1995).

Trail Making Test (TMT), Part B

Part B of the TMT (Reitan, 1958) is used to assess aspects of executive functioning including mental flexibility, attention and sequencing (Spreen & Strauss, 1998). The measure has enjoyed a long history of use as it is easy to administer and takes little time to complete (Lezak, 1995). Subjects are asked to connect a series of circles in a "connect-the-dot" fashion, alternating between a sequence of numbers and letters. The instructions ask participants to complete the task as fast as they can without removing the pencil from the paper. Interrater reliability of the test has been reported to be .90 (Spreen & Strauss, 1998).

Stroop Test (ST)

This test measures components of executive processes including concentration, the ability to shift attentional resources and level of response inhibition (Golden, 1978). There are 3 trials administered to the subject and each has a 45 second time-limit. During the first trial, subjects read words aloud (either "red", "blue" or "green") printed in black ink. Twenty words are printed in each of 5 columns on the page and appear in random order. In the second trial, these words are replaced with X's which are printed in different color inks (either red, blue or green) and the subject is asked to name these randomly listed colors as quickly as possible. The final trial combines both of the preceding stimuli and requires that the subject read the color of ink in which the words "red", "blue" and "green" are printed. This last trial is known as the interference condition because individuals must suppress one percept in favor of another. Lezak

(1995) reports that the ST has satisfactory reliability and more specific test-retest reliabilities are reported by Spreen & Strauss (1998) to be .90, .83, and .91 for the three portions of the ST.

RESULTS

Descriptive Statistics

Means and standard deviations for age, education, occupational level, premorbid IQ, health status and scores on the BDI, GDS and MMSE for this sample are displayed in Table 1. In all, a total of 203 of the 234 participants met screening criteria by demonstrating adequate levels of cognitive and emotional functioning as measured by the MMSE, BDI and GDS. This group of 203 subjects was designated as the final sample for the present study. The average age of the participants was 69.11 (SD = 7.86 years) and ranged from 54 to 87. The sample was well educated as the average level of educational attainment was 15.86 years (SD = 3.02). In addition, on a scale of 1 to 6, mean level of occupation was reported to be 5.07 (SD = 1.18), indicating that most subjects held jobs categorized above that of a skilled laborer (e.g. managerial, official, clerical, sales, self-employment). Finally, on a scale of 1 to 4, average self-reported health status was 1.85 (SD = 0.63), indicating that most individuals rated their overall health as 'good' (as compared to 'excellent', 'fair', or 'poor').

Means and standard deviations for subjects' performance on all dependent measures, including WCST, ST, TMT and SDMT appear in Table 2. A correlation matrix with all measured variables is presented in Table 3.

Power Analysis

A power analysis was conducting to ensure adequate statistical power in detecting small, medium and large effect sizes with the present sample. For significance tests of Pearson Product Moment Correlations, Cohen (1992) defines small, medium, and large effect sizes as .10, .30, and .50 respectively. For a desired power of .80 and with alpha set at .05, Cohen indicates that 783 individuals are needed to detect small effect sizes, 85 to detect medium effect sizes, and 28 to detect large effect sizes of .50 and above. Therefore, the present study has adequate power to detect medium and large effects for correlational analyses but is inadequate for effects smaller than .30.

For significance tests involving multiple regression analyses with 2 independent variables, a desired level of power at .80, and with alpha set at .05, Cohen (1992) indicates that 481 individuals are needed to detect small effect sizes, 67 to detect medium effect sizes, and 30 to detect large effect sizes of .50 and above. Therefore, the present study has adequate power to detect medium and large effects for multiple regression analyses but is inadequate for effects smaller than .30.

Hypothesis 1: Age, Executive Functioning and Speed of Processing

The first hypothesis of the present study sought a confirmation of an age-related decline in measures of executive functioning and speed of processing. As predicted, age was correlated with measures of executive functioning. More specifically, increasing age was associated with poorer performance on both the Trailmaking Test (r=.274, p<.01) and the Wisconsin Card Sorting Test (r=.309, p<.01). However, a significant relationship between age and executive functioning was not clearly demonstrated with the use of the Stroop Test (ST), as this measure did not significantly correlate with age (r=.066). Due to the lack of association between age and the Stroop Test, no further analyses included this particular measure of executive functioning. Therefore, the operationalization of executive functioning in later analyses was limited to the Trailmaking Test (TMT) and the Wisconsin Card Sorting Test (WCST).

As predicted, age was also related to processing speed. More specifically, increasing age was associated with slower performance on the Symbol Digit Modalities Test ($r=-.437$, $p<.01$). Pearson Product Moment correlations between all measures of executive functioning, speed of processing and age are displayed in Table 4.

Composite Scores

Based on the correlations between various measures of executive functioning, a composite score was formed in order to simplify analyses and to avoid overmodelling the data. As displayed in Table 4, the correlation between the two remaining measures of executive functioning, the Trail Making Test (TMT) and Wisconsin Card Sorting Task (WCST), was positive and significant ($r= .21$, $p<.01$). Therefore, a composite score that combined these measures was used as an overall indicator of executive functioning, a technique endorsed by Salthouse and Bobcock (1991). The composite score was derived by converting individual scores from each test to z-scores and then summing them to form a single composite measure of executive functioning. As expected, this new composite score correlated significantly with age such that increasing age was associated with poorer performance ($r=.38$; $p<.01$).

Hypothesis 2: Age, Demographic Variables, and Executive Functioning

Tests for Linearity

Prior to conducting the individual regression analyses to test this hypothesis, the relationship between age and the executive functioning composite score was examined to determine whether or not there were any non-linear components (e.g. quadratic functions). The relationship between age and each of the proposed moderating variables, including education, occupation, health status, premorbid intelligence and gender, was also examined. First, the executive functioning composite score and all demographic variables were regressed on age. Subsequent additions of a quadratic function to the regression models did not produce a significant increase in R^2. Thus, none of the relationships deviated from linearity which simplified all later analyses.

Regression Analyses

Multiple regression analyses were used to test hypothesis 2. These analyses assessed whether individual differences in level of education, occupation, premorbid IQ, gender, or health status would moderate the relationship between age and executive functioning. Separate analyses tested main and interaction effects for each of the demographic variables . The dependent variable for all regression models was the executive functioning composite score. In addition, because regression models necessitate working solely with continuous variables, it was necessary to "dummy code" gender, a categorical variable, by assigning values of 0 and 1. This technique allows the model to properly accept categorical variables for use in the regression equation.

Hypothesis 2 stated that a significant relationship would exist between age-associated cognitive decline in executive functioning and individual demographic variables. That is, lower levels of occupational attainment, fewer years of education, poor health, female gender, and lower levels of premorbid intelligence would be predictive of greater decline in executive functioning with age. Results from individual regression analyses indicate that this hypothesis was not supported, as the identified demographic variables were not shown to be significant moderators in the relationship between age and executive functioning.

The results of the multiple regression analyses appear in Table 5. When age was entered as the sole predictor in Model 1, results indicated that age accounted for 15% of the variance in executive functioning ($p<.01$). Subsequent analyses tested the main effects and interaction effects for education, occupation, gender, health status, and premorbid IQ using 2 models for each variable. In the first model, the demographic variable was entered in combination with age to examine the main effects of the two predictors. In model 2, the interaction variable (e.g. education by age) was entered as the sole predictor of executive functioning in order to test the interaction effect and determine whether the specified demographic variable significantly moderated the relationship between age and executive functioning.

As can be seen in Table 5, none of the interaction effects were significant. R-squared change for the demographic variables failed to reach significance for education (R^2 Change= .010, p=.112), occupation (R^2 Change= .004, p=.359), gender (R^2 Change= .005, p=.283), health status (R^2 Change= .001, p=.722) and premorbid IQ (R^2 Change= .003, p=.388).

Hypothesis 3: Age, Demographic Variables, and Speed of Processing

Tests for Linearity

Prior to conducting the individual regression analyses to test this hypothesis, the relationship between age and speed of processing was examined to determine whether or not there were any non-linear components (e.g. quadratic functions). The relationship between age and each of the proposed moderating variables, including education, occupation, health status, premorbid intelligence and gender, was also examined. First, the processing speed score and all demographic variables were regressed on age.

Subsequent additions of a quadratic function to the regression models did not produce a significant increase in R^2. Thus, none of the relationships deviated from linearity which simplified all later analyses.

Regression Analyses

Multiple regression analyses were used to test hypothesis 3. These analyses assessed whether individual differences in level of education, occupation, premorbid IQ, gender, or health status would moderate the relationship between age and speed of processing. Separate analyses tested main and interaction effects for each of the demographic variables . The dependent variable for all regression models was the processing speed score from the Symbol Digit Modalities Test (SDMT).

Hypothesis 3 stated that a significant relationship would exist between age-associated cognitive decline in speed of processing and individual demographic variables. That is, lower levels of occupational attainment, fewer years of education, poor health, female gender, and lower levels of premorbid intelligence would be predictive of greater decline in speed of processing with age. Results from individual regression analyses indicate that this hypothesis was not supported, as the identified demographic variables were not shown to be significant moderators in the relationship between age and speed of processing.

The results of the multiple regression analyses appear in Table 6. When age was entered as the sole predictor in Model 1, results indicated that age accounted for 22% of the variance in speed of processing ($p<.01$). Subsequent analyses tested the main effects and interaction effects for education, occupation, gender, health status, and premorbid IQ using 2 models for each variable. In the first model, the demographic variable was entered in combination with age to examine the main effects of the two predictors. In model 2, the interaction variable (e.g. education by age) was entered as the sole predictor of processing speed in order to test the interaction effect and determine whether the specified demographic variable significantly moderated the relationship between age and speed of processing.

As can be seen in Table 6, none of the interaction effects were significant. R-squared change for the demographic variables failed to reach significance for education (R^2 Change= .004, p=.313), gender (R^2 Change= .010, p=.120), health status (R^2 Change= .000, p=.979) and premorbid IQ (R^2 Change= .003, p=.365). However, it should be noted that while the interaction effect for occupation also failed to show significance (R^2 Change= .014, p=.059), the trend of this relationship was in the predicted direction. That is, individuals with lower levels of occupational attainment showed somewhat greater decline in speed of processing than individuals with greater levels of occupational attainment.

DISCUSSION

Hypotheses 1 of the present study predicted that age would be significantly associated with decline in measures of speed of processing and executive functioning. This hypothesis was supported. As predicted, age was correlated with a measure of speed of processing, the Symbol Digit Modalities Test (SDMT), such that increasing age was associated with slower performance. This finding is consistent with other research (Cerella, 1990; Hartley, 1986, 1993; Hultsch, Hertzog, & Dixon, 1990; Kail & Salthouse, 1994; Salthouse 1985a, 1992; Schaie, 1989, 1994; Van Gorp, Satz, & Mitrushina, 1990) and demonstrates that normal aging is indeed associated with a general slowing of cognitive processing. This finding lends support to proponents of the general slowing hypothesis (Nettelbeck and Rabbitt, 1992) who argue that the decrease in performance demonstrated by older adults on a variety of cognitive tasks is caused by a general decrease in processing rate with age. In addition, it is important to note that the size of the correlation between age and speed of processing in the present study is consistent with other research. Salthouse (1985) has demonstrated that the median correlation between age and measures of speed across a wide range of behavioral activities is .45. The correlation between age and speed of processing in the present study was .466 ($p < .01$).

As predicted, age was also associated with measures of executive functioning, including the Wisconsin Card Sorting Test (WCST) and the Trail Making Test (TMT). This is consistent with a vast amount of research indicating that executive abilities deteriorate with age (Haaland et al, 1987; Daigneault, Braun, & Whitaker, 1992; Ardila & Rosselli, 1989; Whelihan & Lesher, 1985; Shimamura & Jurica, 1994; Salthouse &

Mitchell, 1990; Burke, 1972; Barr & Giambra, 1990; Pierce et al, 1989). However, one measure of executive functioning used in this study, the Stroop Test (ST), did not significantly correlate with age. This is surprising given the extensive psychological literature indicating a decline in performance on the Stroop Test in older adults (Boone et al., 1990; Cohn et al., 1984; Diagneault et al., 1992; Houx et al., 1993; Macleod, 1991; Ober & Albert, 1985; Spreen & Strauss, 1991; Whelihan & Lesher, 1985). This may be an important finding as it may indicate that performance on this measure does not decline in samples of competent older adults. An alternative explanation may be that decline in the abilities measured by the Stroop Test have already taken place by the time individuals have entered older adulthood, and therefore the test may not be as sensitive to change in older cohorts.

Hypotheses 2 and 3 predicted that a significant relationship would exist between individual demographic variables and age-associated cognitive decline in the areas of executive functioning and speed of processing. That is, lower levels of occupational attainment, fewer years of education, poor health, female gender, and lower levels of premorbid intelligence would be predictive of greater decline with age in measures of executive functioning and speed of processing. These hypotheses were not supported. More specifically, none of the identified demographic variables had a significant moderating effect on the relationship between age and executive functioning or on the relationship between age and speed of processing. Although it was hypothesized that these demographic variables would moderate age-associated cognitive decline, and therefore be identified as risk or protective factors in the aging process, these results were not all-together surprising given the conflicting findings with respect to these variables in the literature. There have been very few studies which have investigated the impact of contextual or demographic variables on age and neuropsychological test performance and those that have been conducted reveal conflicting results with respect to the impact of education (Colsher and Wallace, 1991; Evans et al., 1993; Cobb et al., 1995, Beard et al., 1992), occupation (Brayne and Calloway, 1990; O'Connor et al., 1991; Evans et al., 1997; Bonaiuto et al., 1995), premorbid IQ (Plassman et al., 1995; Snowdon et al.1996), health status (Arbuckle, 1992; Perlmutter and Nyquist, 1990), and gender (Launer et al., 1999; Rocca et al., 1990; Fratiglioni et al., 1991; Bowler et al., 1998). In addition, since the majority of research finding a relationship between these variables and cognitive functioning has been conducted using pathological samples, for example, those with Alzheimer's disease or other dementias, it may be that these variables are in fact moderators of cognitive decline with respect to the development of a dementing illness but do not moderate the decline seen in normal aging. Therefore, it would appear that, at least for some, normal aging can be viewed as a benign process as suggested by Rowe and Kahn (1997).

Another likely explanation for the lack of association between demographic variables and cognitive functioning in the present study may be related to restricted variance among the independent variables. Exclusions from the sample were made when subjects indicated clinical levels of depression and/or exhibited impaired performance on a dementia screening instrument. This was to ensure that the final sample would consist only of those individuals experiencing the normal aging process. However, this was a fairly well-functioning sample and may therefore have encompassed selection biases not controlled for in this study. For example, the sample was a fairly homogeneous group of highly functioning older adults with higher than average education (M=15.86), IQ scores (M=118.83), and occupational attainment. This lack of variation in the sample presumably contributed to an attenuation of the correlations between the variables, making it difficult to detect any moderating effect in the regression analyses. Therefore, future research that investigates the relationship between contextual variables and cognitive functioning in older adults should make attempts to include a more diverse sample.

A third explanation for the lack of association between demographic variables and cognitive functioning may have to do with inadequate power. A power analysis was conducted prior to examining the data. This analyses revealed that the present sample size of 203 subjects was sufficient for detecting medium and large effect sizes, .30 and .50 respectively (Cohen, 1992), but was inadequate for effects smaller than .30. In order to detect smaller effects, a sample size of 481 subjects would be needed (Cohen, 1992). Therefore, it may be that demographic variables indeed have a significant, but relatively small, impact on cognitive functioning with age but the present sample size was inadequately powerful to detect such an effect.

Methodological Considerations

In assessing the quality of empirical work related to age and neuropsychological test performance, it is clear that a number of methodological considerations are needed. Those most relevant to the present study include limitations involved in measuring intended constructs, generalizability of the findings, and the constraints of correlational research.

First, the use of different measures or operational definitions of intended constructs across individual studies has created difficulty in interpretation. Operationally defining the constructs of interest poses an exceptionally troublesome limitation in the research of neuropsychological test performance. What is the most accurate way of assessing constructs such as executive functioning or speed of processing? Unfortunately, experts in the field disagree as to what constitutes an accurate or appropriate definition of such cognitive abilities and often debate about which instruments should be used to adequately measure them. For example, the on-going dispute between Parkin (1998) and Baddeley (1998) regarding the construct of executive functioning poses empirical questions that need to considered when designing any study involving the measurement of executive abilities. Such disagreements highlight the need to use multiple measures when attempting to assess constructs of the sort examined in the present study. Indeed, one strength of this study is that three instruments were used to measure executive functioning, including the Wisconsin Card Sorting Test (WCST), Trail Making Test (TMT), and the Stroop Test (ST). However, it should also be noted that a limitation exists with regard to the measurement of processing speed, as only one instrument was utilized to assess this construct in the present study. Future research should make every attempt possible to include more than one measure of each variable. While the use of multiple measures does not completely solve the issue of construct validity, it does contribute to a more accurate estimation of the construct of interest.

A second limitation in this study is concerned with the generalizability of the research findings. The sample consisted of fairly well-functioning, normal, older adults and was not particularly representative of the socioeconomic, educational, or cultural variation in the general population. While there is undoubtedly interest in understanding the processes of normal aging as it pertains to such individuals, it is important to point out that the conclusions drawn from the present study may not generalize to the larger population of older individuals.

A third limitation is concerned with problems more generally attributed to the nature of correlational and cross-sectional research. Correlational data indicates associations between the variables, but offers no explanation as to why these relationships exist. For example, the present research findings indicate that age is associated with cognitive decline in executive functioning and speed of processing, but causal inferences concerning these variables cannot be made. Although it is necessary to estimate significant relationships, as was done in the present study, it is also necessary to define the mechanisms through which the relationships exist. Such information can only be obtained by conducting non-correlational or experimental research, however, even when using an experimental research design one is not guaranteed the necessary requisites for making causal inferences. Thus, the limitations of correlational research create obstacles for the investigation of many empirical questions and should be carefully considered when designing studies in the field of cognitive aging in the future.

Future Directions

As already mentioned, future research would do well to include samples of individuals which are more heterogeneous with respect to socioeconomic, educational, and cultural characteristics and therefore more representative of the population as a whole. A diverse sample not only helps to avoid the problems associated with restricted variance and attenuated correlations, it also increases the likelihood that results will be generalizable to a more extensive population of older adults.

In addition, future research would likely benefit from the inclusion of a younger comparison group. The comparison of extreme age groups, as opposed to examining data solely from a group of older adults, would be more likely to pick up on and emphasize age-related variance in cognitive performance. Including a younger comparison group would serve to increase the variation in performance assessed and, in turn, more clearly highlight age-related differences in the areas of executive functioning and speed of processing.

Finally, future research may consider the inclusion of both normal, healthy adults as well as those who are functioning at a level inconsistent with normal aging, such as those with Alzheimer's disease or other dementing illnesses. This would not only allow an investigation of the relative impact of demographic variables on the processes of normal aging, but could also assess their impact in the development of pathological diseases processes in later life. As the present study points out, although variables such as education, occupation, premorbid IQ, health status, and gender, were not significant predictors of cognitive decline associated with *normal* aging, they may significantly moderate one's chance of developing a dementing illness. Such empirical questions could not be answered by this study and warrant further investigation.

Summary

It appears that age is significantly associated with cognitive decline in the areas of executive functioning and speed of processing. However, the demographic variables investigated, including gender, premorbid intelligence, level of education, type of occupation, and health status did not significantly moderate the relationship between age and executive functioning or the relationship between age and speed of processing. These findings emphasize the need for future research in this area in order to more clearly elucidate the impact of such variables on the process of normal aging.

APPENDIX

APPENDIX

Table 1

Means and standard deviations for subject's age, education, occupational level, premorbid IQ, health status and scores on the BDI, GDS and MMSE.

Participant Variable	**N**		**Mean (SD)**
	Valid	**Missing**	
Age (years)	203	0	69.11 (7.86)
Years of Education	203	0	15.86 (3.02)
Occupational Level	202	1	5.07 (1.18)
Premorbid IQ	203	0	118.83 (8.48)
Health Status	203	0	1.85 (0.63)
BDI Total Score	203	0	6.33 (4.73)
GDS Total Score	203	0	5.88 (4.92)
MMSE Total Score	203	0	28.37 (1.45)

Table 2

Means and standard deviations for subjects' performance on all dependent measures, including WCST, ST, TMT and SDMT.

Dependent Measure	**N**		**Mean (SD)**
	Valid	**Missing**	
WCST (Total Number of Perseverative Errors)	196	7	16.25 (12.70)
ST (Interference Score)	195	8	4.70 (9.35)
TMT (Difference Score in Seconds)	203	0	56.73 (33.69)
SDMT (Total Number Correct, Oral Portion)	196	7	52.61 (12.46)

Table 3

Correlation matrix for all measured variables.

	Age	Education	Occupation	IQ	Health	Gender	BDI	GDS	MMSE	PS	EF
Age	1.00	.001	.138	-.019	.077	.054	.007	-.026	-.159*	-.466**	.383**
Education	.001	1.00	.446**	.652**	-.166*	-.355**	-.181*	-.155*	.174*	.122	-.284**
Occupation	.138	.446**	1.00	.355**	-.131	-.165*	-.123	-.155*	.111	-.015	-.037
Premorbid IQ	-.019	.652**	.355**	1.00	-.223**	-.088	-.133	-.140	.295**	.262**	-.269**
Health Status	.077	-.166*	-.131	-.223**	1.00	.053	.491**	.440**	-.159*	-.223**	.142*
Gender	.054	-.355**	-.165*	-.088	.053	1.00	.116	.083	.001	-.044	.135
BDI	.007	-.181*	-.123	-.133	.491**	.116	1.00	.772**	-.089	-.080	.168*
GDS	-.026	-.155*	-.155*	-.140	.440**	.083	.772**	1.00	-.135	-.067	.202**
MMSE	-.159	.174*	.111	.295**	-.159*	.001	-.089	-.135	1.00	.272**	-.293**
PS (SDMT)	-.466**	.122	-.015	.262**	-.223**	-.044	-.080	-.067	.272**	1.00	-.381**
EF (Composite)	.383**	-.284**	-.037	-.269**	.142*	.135	.168*	.202**	-.293**	-.381**	1.00

Note. Pearson Product Moment Correlations by listwise comparison N=192. * p value < .05; ** p value < .01.

Table 4

Correlation matrix between age and measures of executive functioning and speed of processing.

	Age	**WCST**	**TMT**	**STROOP**	**SDMT**
Age	1.00	.309**	.274**	.066	-.437**
Executive Functioning:					
WCST	.309**	1.00	.207**	-.189*	-.312**
TMT	.274**	.207**	1.00	-.196**	-.367**
STROOP	.066	-.189*	-.196**	1.00	.090
Speed of Processing:					
SDMT	-.437**	-.312**	-.367**	.090	1.00

Note. Pearson Product Moment Correlations by listwise comparison N=182.

* p value < .05; ** p value < .01

Table 5

Multiple regression analyses predicting the impact of age, education, occupation, gender, health status, and premorbid IQ on the relationship between age and executive functioning.

	Model	Predictors	R2	R2 Change	F Change	Beta	Sig. F Change
Age	1	Age	.150	.150	35.451	.387	.000**
Education	1	Education, Age	.223	.223	28.634	-.270, .390	.000**
	2	**(Education x Age)**	**.232**	**.010**	**2.546**	**-1.023**	**.112**
Occupation	1	Occupation, Age	.158	.158	18.673	-.091, .397	.000**
	2	**(Occupation x Age)**	**.162**	**.004**	**0.846**	**-.605**	**.359**
Gender	1	Gender, Age	.162	.162	19.280	.108, .383	.000**
	2	**(Gender x Age)**	**.166**	**.005**	**1.157**	**.666**	**.283**
Health	1	Health, Age	.172	.172	20.510	.127, .384	.000**
	2	**(Health x Age)**	**.173**	**.001**	**0.127**	**.245**	**.722**
Premorbid IQ	1	IQ, Age	.213	.213	27.109	-.252, .379	.000**
	2	**(IQ x Age)**	**.216**	**.003**	**0.749**	**-.864**	**.388**

Note. ** p<.01

Table 6

Multiple regression analyses predicting the impact of age, education, occupation, gender, health status, and premorbid IQ on the relationship between age and speed of processing.

	Model	Predictors	R2	R2 Change	F Change	Beta	Sig. F Change
Age	1	Age	.223	.223	55.779	-.473	.000**
Education	1	Education, Age	.235	.235	29.658	.109, -.473	.000**
	2	**(Education x Age)**	**.239**	**.004**	**1.024**	**-.660**	**.313**
Occupation	1	Occupation, Age	.223	.223	27.562	.041, -.476	.000**
	2	**(Occupation x Age)**	**.237**	**.014**	**3.594**	**-1.233**	**.059**
Gender	1	Gender, Age	.223	.223	27.757	-.008, -.472	.000**
	2	**(Gender x Age)**	**.233**	**.010**	**2.444**	**.958**	**.120**
Health	1	Health, Age	.254	.254	32.387	-.188, -.453	.000**
	2	**(Health x Age)**	**.254**	**.000**	**0.001**	**.018**	**.979**
Premorbid	1	IQ, Age	.285	.285	38.445	.248, -.465	.000**
	2	**(IQ x Age)**	**.288**	**.003**	**.824**	**-.875**	**.365**

Note. ** $p<.01$

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