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Moderation of age-related cognitive decline in older adults

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MODERATION OF AGE-RELATED COGNITIVE DECLINE IN OLDER ADULTS

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A thesis submitted in partial fulfillment of the requirements for

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ABSTRACT

Moderation of Age-related Cognitive Decline in Older Adults

by

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Prior research has demonstrated a general decline in cognitive performance with age, especially in Fluid Intelligence. This study sought to find a way to slow, halt, or reverse the age-related decline in Fluid Intelligence. Participants aged 50 and older with no prior experience working crossword puzzles worked crossword puzzles for 4 hours per week for 8 weeks. The Constant Group worked easy puzzles for the whole 8 weeks while the Dynamic Group worked easy puzzles for 2 weeks, intermediate puzzles for 3 weeks, and hard puzzles for 3 weeks. All participants were pretested and posttest on 2 measures of Crystallized Intelligence and 4 measures of Fluid Intelligence. Data were analyzed using Analysis of Covariance (ANCOVA) with age as the covariate. Although both groups showed improvement in cognitive performance on most measures results did not reach statistical significance. Trends in the data did not suggest any difference in the scheduling of the intervention task. Results and data trends were interpreted in light of the problem of low N because only 11 participants completed the study.
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CHAPTER I

INTRODUCTION

At the beginning of the Twenty-first Century the United States is experiencing momentous demographic changes. The population is "graying" at a rapid rate. It is estimated that by 2030 more than 65 million Americans will be aged 65 and older. Not only will there be more older adults in America, but by 2030 Americans aged 60 and older will comprise a larger percentage of the population than those aged 14 and under. In fact, by 2030 about 25 per cent of Americans will be aged 60 and older (U. S. Bureau of the Census).

The increase in longevity is good news for those alive today. But there is more to living than merely remaining alive. Older adults want to enjoy their added years, and to do this they need to remain physically and mentally capable for as long as possible. The purpose of this study was to explore one possible way for older adults to improve and retain their mental abilities into old age.

Although common sense tells us that aging results in certain inevitable changes in the human organism, researchers do not always agree which of these changes are inevitable (Botwinick, 1967). For example, many studies have demonstrated age-related declines in cognitive functioning (for a review of these studies see Salthouse, 1991). A gradual decline in cognitive performance is fairly universal, but research has demonstrated that there is a great degree of variability in this decline. Salthouse (1991) analyzed thousands
of studies and concluded that the decline is differential. Some cognitive abilities remain relatively stable and do not show a decline until late in life, while other cognitive abilities show large declines beginning early in life.

The variability in age-related cognitive decline corresponds well with Horn and Cattell’s division of intelligence into Crystallized and Fluid Intelligence (Horn & Cattell, 1966). Horn and Cattell divided cognitive abilities into two major categories. The first they called Crystallized Intelligence, which consists of early-learned and over-learned knowledge (e.g., vocabulary and grammar) and repetitive skills (e.g., riding a bicycle and throwing a ball). The second category they called Fluid Intelligence, which consists of such abilities as memory for recent events, reasoning processes, and abstract thought. New learning requires the use of Fluid Intelligence. Research indicates that Crystallized Intelligence remains relatively stable throughout life and starts to decline only in the sixties or seventies. In contrast, for most people Fluid Intelligence starts to decline in the thirties and declines more rapidly in the forties and beyond (Horn, 1982; Horn & Cattell, 1966; Salthouse, 1991).

Certainly both types of intelligence contribute to successful living. Since Fluid Intelligence declines earlier and more rapidly, this age-related decline is of special concern. Fluid Intelligence contributes greatly to quality of life because it is needed to learn new information and solve new problems. Even simple situations such as remembering where your car is parked require an exercise of Fluid Intelligence. Loss of fluid abilities makes humans less capable of adapting to new situations, solving new problems, and learning new information; this can have a negative impact on quality, and perhaps quantity, of life. Palmore (1982) determined that intelligence was a good
predictor of longevity. Moreover, he found that scores on the performance component of
the Wechsler Adult Intelligence Scale (the fluid component) were better predictors of
longevity than scores on the verbal component (the crystallized component). Researchers
have recognized the importance of maintaining cognitive performance throughout life,
and they have attempted in a variety of ways to slow or stop the cognitive decline that
comes with advancing age.

Cognitive performance is measured by psychometric tests of intelligence. Many such
tests have been devised and used over the years, and a large body of data from these tests
already exists (e.g., Salthouse, 1991). Generally, researchers have divided into two
camps with regard to their views on the nature of cognition.

One group follows the analytic approach and sees cognition as the sum of many
independent and unrelated mental processes. Those who hold this view believe that each
psychometric test measures a separate and independent mental ability and that each
ability is unrelated to other abilities. Researchers who adhere to this opinion attempt to
impact only one cognitive ability at a time by training subjects on just one particular
ability. These researchers do not expect the training to have an effect on any ability
except the one ability trained. In fact, researchers have been successful in improving the
cognitive performance of older adults on psychometric tests of specific abilities by using
this technique (e.g., Kliegl, Smith, & Baltes, 1989; Willis & Schaie, 1986). However, the
disadvantage of this approach is that these training techniques produce very little if any
transfer of the training effects (improvement) to other cognitive tasks that were not
trained (Hayslip, 1989). Therefore this approach is not very practical because there are
many specific cognitive abilities, and if each must be trained separately to produce
improvement then the job is overwhelming because of time and money constraints.

In contrast to the above point of view, some researchers view intelligence as a single entity. They argue that psychometric tests really measure different aspects of one underlying general intelligence. They view intelligence as some sort of resource or power that underlies and drives all the specific mental abilities measured by psychometric tests of intelligence. In fact, they argue that each psychometric test actually measures two things: the specific mental ability it was designed to measure and the underlying resource or general intelligence. The first and foremost proponent of this resource approach was Spearman. In 1923 Spearman hypothesized that intelligence is based on two factors (his two-factor theory). One factor he called the specific factor which he designated "s." The s factor is a specific mental ability such as word recognition or inductive reasoning. Every psychometric test ostensibly measures an s factor. The other factor Spearman called the general factor which he designated "g." He argued that the g factor is some sort of general underlying and empowering ability that enables or powers all the individual s factors. He regarded the g factor as general intelligence. He also said that each psychometric test measured not only some specific s factor but also the g factor, at least to some extent (Spearman, 1923). Researchers who adhere to Spearman's viewpoint take a resource approach to intelligence rather than the analytic approach.

The resource approach offers a more practical way to attack the problem of declining intellectual performance. If this approach is correct, then any intervention which improved the functioning of the underlying resource (the g factor) should also lead to improved performance in a number of specific mental abilities (s factors). If a way could be found to impact the g factor then many specific cognitive abilities could be improved.
through one intervention. Such an approach could yield widespread improvements in cognitive functioning with much less expenditure of time and money. Thus the resource approach promises a more practical method for influencing cognitive functioning than the analytic approach.

Salthouse (1991) has stated that the data tends to support the resource view of cognition rather than the analytic view of cognition. Most psychometric tests are correlated with each other to some degree, which suggests that they are measuring something in common (the g factor or general intelligence) and not just isolated and independent abilities (s factors). No one has identified the exact nature of the g factor, which makes it difficult to find an intervention that will impact it. The g factor could be any of three capacities: processing speed (time), working memory capacity (space), or attentional capacity (energy); or it could be any two of these or even all three (Spearman, 1923; Bickley, Keith, & Wolfe, 1995).

The present study was based on the resource approach exemplified by Spearman's g, and it was designed to determine the effect of a general intervention program on six tests of cognitive performance. The intervention task used was the working of crossword puzzles, which was different from the tasks of the six dependent measures. It was hypothesized that the intervention task would impact general intelligence (g) and in turn would impact some or all of the dependent measures.
CHAPTER 2

LITERATURE REVIEW

Introduction

Crystallized Intelligence represents the degree to which a person has incorporated knowledge and can use it to solve practical everyday problems. Verbal comprehension, word knowledge, arithmetic ability, practical judgment, and common sense are examples of crystallized abilities. The verbal scale of the Wechsler Adult Intelligence Scale (which is composed of subtests of general information, comprehension, arithmetic, similarities, digit span, and vocabulary) is presumed to measure crystallized abilities. The development of these abilities is thought to be influenced more by culture than by the biological state of the brain, which may account for the fact that these abilities increase until late in life, even into the seventies, and decline only near the end of life in healthy individuals (Rybash, Roodin, & Hoyer, 1995).

Fluid Intelligence involves the basic operation of the human information processing system. Fluid abilities include sensation, perception, attention, inductive reasoning, and the ability to form concepts and associations. The performance scale of the WAIS (which is composed of digit symbol, picture completion, block design, picture arrangement, and object assembly subtests) is presumed to measure fluid abilities. Fluid Intelligence is a person's ability to perceive, remember, and think about information, and includes such activities as discerning patterns, drawing inferences, and understanding
implications. Fluid Intelligence does not depend on culture, but on the biological state of
the brain and the integrity of the central nervous system (Horn, 1982; Rybash et al.,
1995). These abilities exhibit early and large declines beginning in the thirties.

Because fluid abilities reflect the biological state of the brain, and because they are so
important to human functioning (especially learning), scientists have made attempts to
slow, halt, or reverse the decline in Fluid Intelligence. The procedure used has been to
identify a particular ability measured by a specific psychometric test and then train
subjects in that ability. In general these attempts have been successful to varying
degrees.

The Study of Salthouse and Somberg

Salthouse and Somberg (1982) performed a seminal study in this area. A review of
prior studies led them to conclude that perceptual performance on visual and hearing
tasks could be improved with practice. They also observed that data support the
conclusion that performance on motor tasks can be improved significantly through
practice. Reaction time can be reduced and effectiveness improved by extensive practice.
They sought to determine the mechanism responsible for these improvements in
performance. They hypothesized three possible explanations. First, improvement might
result from a change in the type of information being processed. Perhaps practice
enabled subjects to distinguish relevant from irrelevant information more effectively, or
categorize or organize information more efficiently. A second possibility was that
practice might lead to a change in the way information was processed. Perhaps with
practice certain information processing stages could be skipped, or information that had
been processed serially could now be processed in parallel. A third possibility was that
practice reduces the attention requirements of the task. Some processes might become automatic and not need conscious control.

Salthouse and Somberg noted that prior experiments had shown significant age differences in task improvement with practice. Even after practice, older adults still performed more slowly and less accurately than young adults on perceptual and motor tasks. But they also noted that past experiments all used subjects who were inexperienced at the intervention task and performed the tasks for a relatively short time (the experiments were of short duration). They decided to investigate the relationship between the amount of experience with a task and the age difference in performance of that task. They reasoned that if unfamiliarity was largely responsible for the age differences in performance then these performance differences should disappear with extensive practice. However, if physiological or biological differences between young and old adults were responsible for the performance differences then no amount of practice would make the age-related performance differences disappear. They designed a two-phased experiment to determine if age differences in performance could be eradicated with sufficient practice. In the first phase 50 young and 24 older adults played a “Space Trek” game composed of signal detection, memory-scanning reaction time, visual discrimination, and temporal-anticipation tasks; the subjects performed the tasks during a single session to establish normative levels of performance for the two groups. In the second phase 8 young and 8 older adults played the “Space Trek” game for 51 sessions extending over 2 to 5 months. The effects of practice were examined by comparing performance at various levels of experience with the tasks. The experimenters
tried to investigate the underlying mechanisms by using several transfer conditions and periodically introducing a concurrent reaction time task.

Results showed that both young and old adults significantly improved their performance on elementary tasks with practice. The researchers suggested this shows that acquisition of a complex skill involves more than just improved timing or coordination of components; the actual components of the task can be improved with practice. The authors stated that there was some evidence that practice-related improvement resulted from a change in the type of information being processed. The results of one of the experimental tasks also supported the hypothesis that practice-related improvement might be caused by a change in the sequence of information processing operations. The evidence was mixed with regard to the hypothesis that practice-related improvement was due to reduced attentional demands with practice. Therefore the results supported three mechanisms for practice-related improvement: changes in the type of information being processed, changes in information processing operations, and reduction in the amount of resources (attention) required.

With regard to adult age differences in improvement, the researchers concluded that both young and old adults can improve, and improvement may be even greater in older adults than in young adults. But despite these improvements, significant age differences in performance remain no matter how much practice the older adults receive. Both young and old adults perform and improve tasks the same way. The ability to acquire and retain simple perceptual and cognitive skills is not impaired by age; however, even extensive practice will not eliminate age differences in performance. Older adults go through the same information processing operations as young adults, but at a slower
speed. The age differences in performance are due neither to different strategies nor to differences in experience. The age differences in performance are more probably due to a fundamental physiological change in the nervous system which results in a slower rate of information processing.

**More Recent Studies**

Scientists have continued to search for the cause of the cognitive decline suffered by many older adults. Much research supports the speed hypothesis, which says that age differences in intellectual performance are due primarily to age differences in the speed of information processing (Lindenberger, Mayr, & Kliegl, 1993). Speed is a task-unspecific resource and declines in processing speed could negatively impact many or all cognitive abilities. Lindenberger et al. (1993) tested 141 older adults between the ages of 70 and 103 years using 14 different measures of 5 abilities: speed, the fluid abilities of reasoning and memory, and the crystallized abilities of knowledge and fluency. Analysis of the data provided strong support for the speed hypothesis. Differences in processing speed mediated the age differences in not only the fluid abilities (reasoning and memory) but also the crystallized abilities (knowledge and fluency). Speed alone and age plus speed together accounted for 80.6% of the variance in intellectual functioning. The researchers concluded that either processing speed is the critical resource that limits intellectual functioning with age or speed measures are the best indicators of some other age-related process or processes that negatively affect intellectual abilities. Either way, psychometric measures of processing speed are powerful predictors of age differences in intelligence among older adults.
Another route of exploration has been the investigation of age differences in working memory. Working memory involves the cognitive processes used to manipulate and temporarily store information while planning or controlling other mental operations (Campbell & Charness, 1990). Age differences in intellectual performance may be mediated by age-related decrements in working memory function. Campbell and Charness (1988, 1990) tested the working memory of older adults by comparing the performance of young, middle aged, and older adults on an arithmetic task. Participants were given an algorithm for squaring two-digit numbers, with all calculations performed in short term (working) memory (a mental squaring task). Before practice, the older adults performed worst, followed by the middle aged, and then the young. After practice, pure arithmetical calculation errors were reduced for all three groups to the point that the old performed just as well as the middle aged and not much worse than the young. But working memory errors, errors in information manipulation and management, exhibited significant age differences even after practice. All three groups reduced their working memory errors across practice, and the old improved to the point that their working memory error rate declined to the pre-practice level of the young, but the age differences in working memory error rate remained relatively stable. Older adults were more prone to difficulties associated with working memory operations than the young or middle aged. The deficit in working memory efficiency was resistant to change with practice. The researchers suggested that slower information processing speed may account at least in part for the loss of working memory efficiency because the duration of information in working memory is known to be limited, and lengthening the time needed for processing
increases the likelihood that information will decay and be lost from working memory before the information can be manipulated and reused.

Other scientists have investigated working memory in older adults. Salthouse and Babcock (1991) view working memory as a dynamic interplay of three components: processing efficiency, storage capacity, and coordination effectiveness. They studied how these three components contributed to age-related differences in working memory function. Results confirmed that increasing age is associated with progressively decreased performance on working memory tasks. Their studies revealed that decline in processing efficiency had the greatest impact on working memory, and simple processing speed (the speed of executing elementary operations) is the factor most responsible for the decline in processing efficiency. Age differences in working memory may be mediated primarily by age-related reductions in processing speed.

The decline in working memory effectiveness that occurs with advancing age may account for age-related differences in performance on many cognitive tasks. If older adults have greater difficulty with simultaneously storing and processing information, this may explain age differences in performance on cognitive tasks because measures of mental abilities rely on working memory. Salthouse and Skovronek (1992) attempted to determine how age-related limitations in working memory might lead to general impairments in cognitive function. They conducted a series of five studies comparing the performance of young and old adults on a cube comparison task that measured the availability of different types of information while participants were attempting to solve the task. The young outperformed the old, but the data indicated that the age differences in performance were not due to failures to perceive and record information temporarily.
but were due to decrements in various types of processing operations that needed to be performed on the information. The researchers concluded that the young and old are equally effective at encoding and preserving information without transforming or processing the information; however, increasing age results in progressively greater difficulty with simultaneously storing and transforming or abstracting information. The solution to many cognitive tasks requires the transformation or abstraction of temporarily stored information, so older adults are definitely at a disadvantage in tasks that require these types of mental processes.

Plasticity, Reserve Capacity, and Testing the Limits

Although the Salthouse and Somberg (1982) study suggested that older adults could never perform as well as young adults on perceptual and motor tasks, it did show that older adults could benefit greatly from practice, probably even more than young adults, and could greatly improve their performance. Since this study many researchers have explored ways to improve the cognitive performance of older adults, and many have succeeded.

Paul B. Baltes and his associates have investigated methods for improving fluid abilities in older adults. Their experiments have led them to formalize the concepts of plasticity, reserve capacity, and testing the limits. Plasticity refers to the capacity of the human brain to change and develop over time (modifiability). Reserve capacity refers to unused potential in the human brain and the ability to improve performance on mental tasks; the idea is that humans possess more cognitive ability than they normally use. Testing the limits is the strategy employed by Baltes and his associates to take advantage of the plasticity and reserve capacity of older adults to improve their cognitive
functioning; it involves training techniques that challenge the cognitive abilities and stress the mental systems of older adults.

Baltes, Dittmann-Kohli, and Kliegl (1986) investigated the plasticity and reserve capacity of older adults with a 6 month longitudinal study. They used a pretest-training-posttest design with an experimental and a control group. The sample consisted of 204 older adults (age range 60 to 86; mean age 72). After the pretest the participants were given 10 training sessions over a 1 month period on the fluid abilities of figural relations and induction. Results showed significant improvements on all dependent measures for the experimental group. Training effects persisted at posttests 1 week, 1 month, and 6 months after training. There was also some transfer of training effects to other near-related tests of figural relations and induction, but no general transfer to other fluid abilities as measured by the Raven Advanced Progressive Matrices test. Both the young-old (below age 70) and the old-old (aged 70 and older) exhibited substantial gains in performance. This study replicated findings from earlier studies conducted by Baltes and his associates. It demonstrated that older adults have an extensive reserve capacity. But the researchers pointed out that this study did not provide evidence that intelligence in general could be raised, although they did suggest that training which was wider in scope might produce a rise in general intelligence.

Baltes and Lindenberger (1988) reviewed 15 years of research on cognitive plasticity in older adults. They concluded that the evidence is convincing: Older adults definitely possess substantial plasticity and reserve capacity to improve their performance on tests of intelligence and cognitive ability. Older adults can improve their performance on fluid ability tests and the training effects can persist for at least 6 months. However, transfer of
training effects is very narrow and limited to near-transfer tests. Nevertheless, older adults can reactivate knowledge and skills they once exercised and can acquire new knowledge and skills.

The testing the limits strategy delineates the latent potential or zone of possible intra-individual improvement. Testing the limits involves varying the levels of difficulty of tasks and challenging individuals to expand their limits of performance. Past research suggests that as you move from normal to maximum levels of functioning, age differences are magnified and robust to the point of irreversibility. Therefore aging is accompanied by continued plasticity but reduced limits to plasticity (less reserve capacity). Despite the narrowing of reserve capacity, older adults are still capable of improving performance on fluid intelligence tasks to high levels of expertise (Baltes & Lindenberger, 1988).

Kliegl, Smith, and Baltes (1989) attempted to determine the limits of reserve capacity (which they called developmental reserve capacity) following an intervention. They used the testing the limits method to approach, step by step, maximum levels of performance. They compared young adults (ages 19 to 29) to older adults (ages 65 to 83). Both groups were trained in the Method of Loci to perform a serial word recall task. Results showed that both the young and the old have sizable reserve capacity (ability to improve performance), but in this study the young benefited more from the intervention than did the old. At expert levels of performance age differences were magnified; not only did the mean performance of the young improve more than the mean performance of the old, but the ranges of performance barely overlapped (the best performance among the old adult group was barely better than the worst performance among the young adult group). The
researchers felt that these results could not be explained by lack of task experience or disuse of abilities, but were most likely caused by physiological limits of the aging brain. Once again, however, the results clearly demonstrated that trained older adults could far outperform untrained younger adults, and they could increase their performance greatly above baseline. In 1990 the same three researchers conducted another experiment using the Method of Loci as the intervention and obtained essentially the same results (Kliegl, Smith, & Baltes, 1990).

In 1992 Baltes and Kliegl performed yet another experiment using the Method of Loci as the intervention. The results supported prior findings and firmly convinced the researchers that, despite substantial reserve capacity, older adults experience a robust and probably irreversible decline in fluid intelligence due to biological age-related changes in the brain. They stated that it was very unlikely such pronounced and extensive age differences in performance could be explained merely by cohort effects.

Variability and Improvement

Cognitive decline among older adults exhibits much inter-individual variability. Some older adults show decrements in many abilities, some show decrements in one or only a few abilities, and some show no decrements in any abilities (Willis & Schaie, 1986). Despite the degree or extent of cognitive decline, it appears that all healthy older adults can benefit from cognitive interventions. Willis and Schaie (1986), using a pretest-treatment-posttest control group design, tested 107 participants on the fluid abilities of spatial orientation and inductive reasoning and divided them into four groups: (1) those who had declined in spatial orientation but not in inductive reasoning, (2) those who had declined in inductive reasoning but not in spatial orientation, (3) those who had
declined in both abilities, and (4) those who had not declined in either ability. After two weeks of training on the two abilities all groups exhibited significant improvement in the areas trained. The results demonstrated that even older adults who have not suffered cognitive decline can improve their performance through training. However, the training effects did not transfer to other primary mental abilities.

Even old-old adults can benefit from cognitive interventions and their performance can be improved by multiple interventions over a considerable time period (Willis & Nesselroade, 1990). Willis and Nesselroade conducted a longitudinal study with three training interventions. The study used a pretest-treatment-posttest control group design. The mean age of the participants advanced from 69 to 77 years over the course of the study with training interventions at mean ages of 69, 71, and 77 years. The fluid ability trained was figural relations. Results demonstrated that even into advanced old age older adults could improve their performance significantly on this fluid ability. The training intervention used was specific to the figural relations task and was a laboratory constructed and administered training program. Encouraged by their results, the researchers suggested that future researchers explore more naturalistic types of activities that enhance and maintain cognitive functioning.

Older adults may be able to achieve significant performance gains through self-training. Baltes, Sowarka, and Kliegl (1989) used a pretest-treatment-posttest control group design to determine if older adults could conduct their own training program and still improve as much as a group trained by a tutor. Training time and training materials were the same for both training groups; the only difference was that one group received instruction from a tutor, while the other group used the same training materials without a
tutor. The ability trained was the fluid ability of figural relations. Both groups achieved the same improvement in performance. Although the training program used was developed by researchers and used in a laboratory setting, this study was encouraging because it suggested that older adults might be able to achieve significant improvement in cognitive functioning through self-administered training programs.

Another study suggested that older adults may be able to acquire memory enhancement protocols through self-training (Scogin, Storandt, & Lott, 1985). Participants studied a 92 page manual at home; the manual taught mnemonic skills and provided at-home practice. The training program proved effective and significantly improved performance on a number of measures. However, a 3 year follow-up study on the same participants showed that their memory performance had returned to pre-training levels and most participants no longer used the mnemonic devices learned in the original study. The participants had not used the mnemonics in their daily lives after the conclusion of the original study and thus had forgotten them (Scogin & Bienias, 1988).

West and Crook (1992) used a take-home videotape as a self-administered training technique. Their study employed two groups: the training group (mean age 61.5) and the waiting list group (mean age 60.8). The training group received a training tape on how to use visual imagery to improve memory for long-term recall; training was given on name recall, list learning, and location recall. Pretests and posttests were administered on these three variables plus the transfer variables of incidental memory, first-last names, and face recognition. Results showed that, on the trained variables, the training group significantly outperformed the waiting list group on the posttest, and the training effects were maintained for 1 week. The results for the transfer tests did not reach significance.

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but showed a positive trend. The researchers concluded that the self-paced, self-administered training technique (videotape) was successful, and it was also much less costly and more easily administered than conventional laboratory training methods.

Memory training techniques such as the Method of Loci have been shown to improve the memory performance of older adults. Immediate or temporary improvement, however, is not the only goal. Scientists also wish to effect long-term improvement and to give older adults memory enhancement techniques that they can and will use in their daily lives. Some researchers have explored the long-term effects of memory training. One such project taught the Method of Loci to a group of older adults aged 66 to 85. The training succeeded in improving the memory performance of the participants. After three years the researchers recalled the original participants and presented them with memory tasks identical to those used previously. The participants did not use the Method of Loci when performing the new memory tasks and their performance on the new tasks was no better than pre-training performance levels. The participants acknowledged that the Method of Loci was an effective and useful technique for improving memory, but still they did not use it in their daily lives. The researchers suggested that the older adults might not have viewed the memory tool as relevant to their lives, instead regarding it as nothing more than a game to be played in the artificial setting of the laboratory. They concluded that training techniques need to be found that older adults will use for everyday memory tasks (Anschutz, Camp, Markley, & Kramer, 1987).

The improvement in cognitive function that has been obtained through laboratory training methods has been shown to be durable (e.g., Neely & Backman, 1993; Hayslip, Maloy, & Kohl, 1995). But older adults usually fail to use these laboratory techniques...
(such as the Method of Loci) in their daily lives (Anschutz et al., 1987). Even memory researchers who spend their professional lives investigating memory improvement techniques and are well aware of their efficacy do not use these techniques in their daily activities (Park, Smith, & Cavanaugh, 1990). If even the experts in the field do not view their training techniques as having practical value, how can older adults be expected to adopt these techniques in their daily lives? What is needed is a method for improving cognitive functioning that is cheap, easy to use, easily accessible to people of all socio-economic standing, and sufficiently enjoyable or interesting to be used on a regular basis.

The present study explored the possibility that crossword puzzles may be just such a method for improving cognitive functioning. Crossword puzzles are inexpensive, available to almost everyone, and enjoyed by many people of all ages. The present study used crossword puzzles as an intervention task. Participants were pretested on six measures of cognitive functioning (two measures of crystallized abilities and four measures of fluid abilities), worked crossword puzzles for 32 hours over an 8 week period, then posttested on the same measures to see if the intervention task produced any significant improvement on any of the dependent measures. Participants were older adults who had no significant prior experience working crossword puzzles. The intervention task was a new cognitive challenge for them. Completion of crossword puzzles requires knowledge of vocabulary and general information as well as the use of working memory, attention, reasoning, and long-term memory (both crystallized and fluid abilities). For one group (the Dynamic group) the difficulty of the puzzles was increased from easy to medium to hard over the course of the study to eliminate practice
effects and to determine if the scheduling of the task rather than the mere performance of the task had an impact.

Other researchers have attempted to determine the relationship, if any, between crossword puzzle proficiency and age-related cognitive decline. Hambrick, Salthouse, and Meinz (1999) conducted a complex experiment involving four separate studies to determine what factors contribute to the solution of crossword puzzles and to find moderator variables for the relation between age and both crystallized and fluid intelligence. They used correlation, multiple regression analysis, and structural equation analysis to analyze data on numerous dependent measures obtained from four separate samples. Their general conclusions were that general knowledge was a good predictor of crossword puzzle proficiency but abstract reasoning ability had no relation to puzzle proficiency, and that crossword puzzle experience does not reduce age-related declines in fluid intelligence nor enhance crystallized intelligence. At first glance their conclusions appear to be evidence against the research hypothesis of this study. However, this is not the case. The samples used in the Hambrick-Salthouse-Meinz experiment were not representative of the population represented by the sample used in this study. The present study examined participants who were aged 50 and over and had no prior experience working crossword puzzles. The Hambrick-Salthouse-Meinz experiment used samples composed of participants aged 19 to 80, and in all four studies the majority of participants were aged 60 and under. These participants also had extensive experience throughout their lives solving crossword puzzles. Considering the biased samples used, the conclusion of the three researchers that crossword puzzle experience does not reduce age-related cognitive decline seems questionable. Among a population of puzzlers over a
large age range, puzzling may not be a reliable predictor of cognitive performance nor a moderator of age-related cognitive decline. But this does not rule out the possibility that among the general population of older adults puzzling may be a good predictor of cognitive functioning or may have a causal relationship to cognitive performance. Neither the Hambrick-Salthouse-Meinz experiment nor any other reported experiment has attempted to test the hypothesis tested in this study by using crossword puzzles as an intervention task to see what impact it may have on the cognitive performance of non-puzzler older adults.

Neurobiology

The aging brain undergoes a number of biological changes such as loss (death) of neurons, decline in the production of acetylcholine, and an increase in neurofibrillary plaques and tangles. These changes are detrimental to cognitive functioning (Rybash et al., 1995). But not all age-related changes in the brain are detrimental. With age comes an increase in the number and branching of dendrites. Researchers have observed a net increase in dendritic growth in the hippocampus and the neocortex, areas of the brain critical for memory and learning (Buell & Coleman, 1981; Coleman & Flood, 1987). It appears that the human brain compensates for neuronal loss by increasing the number of dendritic connections among remaining neurons. Normal aging produces dendritic growth, but abnormal aging (such as senile dementia with its corresponding loss of cognitive functioning) results in reduced dendritic branching and connections (Buell & Coleman, 1981).

Experiments with rats have produced the same findings. Older rats were found to increase their dendritic branching when they were placed in a complex and challenging
environment. These studies suggest that dendritic growth can be stimulated by increasing the demands on remaining neurons. Both growth and degeneration of dendrites can occur at the same time, but growth can predominate over degeneration if the brain is exercised sufficiently (Green, Greenough, & Schlumpf, 1983; Greenough, McDonald, Parnisari, & Camel, 1986).

Until recently it was thought that the human brain remained relatively stable and unchanging after infancy. It was long believed that humans did not produce any new neurons after birth and that most neural connections were genetically determined and firmly fixed by late infancy. Recent research has provided a new understanding of brain function and organization. Studies of amputees and their phantom limb phenomena have shown that the human brain remains quite plastic into adulthood. After a limb is lost, the brain remaps itself by creating new neural connections to accommodate changed sensory inputs. Environmental experiences can produce functional changes even in adult brains. The adult brain is in fact very biologically dynamic (Ramachandran, 1995).

Perhaps the most surprising discovery is that adult human brains experience neurogenesis. It was long known that other mammals such as mice, rats, and marmoset monkeys produce new neurons in adulthood. Only recently did researchers discover that humans too produce new neurons in adulthood. Studies have demonstrated that the human hippocampus retains its ability to generate neurons throughout life. Experiments have also shown that environmental factors can impact neurogenesis. Aging and stress can inhibit new neural production, while enriched and challenging environments can increase the generation and survival of new neurons. The proper environment can stimulate new learning and the incorporation of new neurons into new neural connective
pathways. But if new neurons do not connect with other neurons to form functional neural connections then the new neurons will die within a few weeks of creation (Eriksson, Perfilieva, Bjork-Eriksson, Alborn, Nordborg, Peterson, et al., 1998; Gould, Tanapat, Hastings, & Shors, 1999).

Conclusion

Aging is accompanied by a decline in cognitive functioning as evidenced by a large body of data from psychometric tests. Training interventions can improve the cognitive functioning of older adults, sometimes to the point where trained older adults function at the level of untrained young adults. Older adults definitely benefit from cognitive training. Although improvement has usually been specific to the task trained, the resource approach to cognition suggests that it may be possible to find a training intervention that will impact general cognitive performance. If a practical intervention that positively impacted general intelligence (g) could be found, then general cognitive performance could be improved in an efficient and cost-effective way that would make the benefit available to all older adults. Research suggests that providing a general cognitive challenge may be one way to improve cognitive functioning. Recent findings in neurobiology show that the mechanisms for cognitive change may be neurogenesis, dendritic growth, and the formation of new neural connections in the adult human brain, and that one possible way to activate these mechanisms is to stimulate the brain with a challenging environment that requires new learning.

Research Hypotheses

One research hypothesis of this study was that a novel cognitive challenge (crossword puzzles) given to older adults would impact their general cognitive ability (g). A second
hypothesis was that increasing the difficulty of the intervention task over the course of the study would have a greater impact on the cognitive ability of older adults than a task with a constant level of difficulty. The intervention was lengthy (32 hours over 8 weeks). For one of the two groups the difficulty level of the intervention task was maintained at a high level (i.e., practice effects were offset) by increasing the difficulty of the puzzles throughout the course of the study. Dependent tests measured several general cognitive abilities (speed of information processing, working memory, attention, long-term memory) to determine if the intervention task did impact general cognition (g). Past research suggested that an experiment with this design might provide support for the research hypotheses.
CHAPTER 3

METHOD

Participants

Participants were 17 older adults aged 50 and above recruited from the local metropolitan community. Three were male and 14 were female, aged 63 to 76, with a mean age of 69.71 and a standard deviation of 4.13. Each participant received one chance to win $100.00 in a lottery as compensation for participation. All participants were screened to ensure that they had no prior significant experience working crossword puzzles. Anyone who had worked more than 24 puzzles over the past 3 years would have been excluded; none of the participants had worked more than a few puzzles over his/her lifetime. All participants also were screened with regard to health conditions that might affect performance on the cognitive tests that were the dependent measures; none of the participants had any disqualifying health condition. A copy of the screening form is included in Appendix A. All participants signed an informed consent form prior to their commencement of the study. A copy of the informed consent form is included in Appendix B. The Office for the Protection of Research Subjects, University of Nevada, Las Vegas approved the design and methods of this study prior to the commencement of data collection. A copy of this approval is included in Appendix C.
Experimental Design

This study was a 2 [Group (Constant and Dynamic)] x 2 [Test (Pretest and Posttest)] mixed design. The two levels of Group were the Constant Group and the Dynamic Group; Group was a between subjects factor. The two levels of Test were Pretest and Posttest; Test was a within subjects factor. There were six dependent measures divided into two categories: tests of Crystallized Intelligence and tests of Fluid Intelligence. The two tests of Crystallized Intelligence were: (1) The Information subtest from the Verbal Scale of the Wechsler Adult Intelligence Scale – Revised (WAIS-R), and (2) the Vocabulary subtest from the Verbal Scale of the WAIS-R. The four tests of Fluid Intelligence were: (1) the manual Stroop task, (2) the automated Stroop task, (3) a precued reaction time task, and (4) a pattern comparison task (Salthouse & Babcock, 1991).

Materials and Apparatus

The materials and apparatus consisted of crossword puzzle books, crossword puzzle dictionaries, paper tasks, and a desktop personal computer with installed programs. The crossword puzzle books were Superb Crosswords, Volume 67, Number 7 dated May 3, 1999, and Number 10 dated June 21, 1999, published by Official Publications. Both issues (Numbers 7 and 10) contained crossword puzzles rated easy, medium, and hard by the publisher. The crossword puzzle dictionary was Webster’s Crossword Dictionary published by Kappa Books in 1997. The paper tasks were the paper form of the manual Stroop task and the Salthouse and Babcock (1991) pattern comparison task. The computer was a Gateway 2000 486/33c IBM compatible personal computer with
Gateway keyboard and mouse, and a NEC/MultiSync 4 D S monitor, with computer programs for the precued reaction time and automated Stroop tasks installed.

Procedure

Participants were divided into five-year age groups (ages 50 through 54, 55 through 59, etc.). The first participant in a five-year age group was assigned to one of the two groups (Constant or Dynamic) and the next participant in the same age group was assigned to the other group, until all participants had been assigned to groups. In this way the two groups (Constant and Dynamic) were pair-matched by age to ensure that the mean age of each group was nearly equal. The Constant Group had 8 participants with a mean age of 70.13 years and a standard deviation of 4.61, and the Dynamic Group had 9 participants with a mean age of 69.33 years and a standard deviation of 3.91. The two groups were not significantly different with regard to age, $F(1,16) < 1$.

All participants were pretested on all six dependent measures. The two tests of Crystallized Intelligence (the Information and the Vocabulary subtests of the WAIS-R) were administered in accordance with the standard protocol for the WAIS-R. Both the questions and the answers were spoken and tape-recorded. Participants were tested one at a time.

For the Information subtest, the test was divided into odd and even questions to produce two versions of the test, versions A and B, with 14 questions in each version. The versions were counterbalanced so that every participant received a different version of the test at pretest and posttest. The Information subtest consisted of questions that became progressively more difficult from the first question through the last. The questions tested the participants' knowledge of general information about everyday
matters. The protocol provides the correct answers for questions that have only one answer, and examples of acceptable answers for questions that permit a range of correct answers. Participants were given as much time as they desired to answer the questions (this was not a timed task). The researcher asked each question exactly as it was written, and the participants answered in their own words. If a participant gave a partial or unclear answer the researcher prompted with "Explain what you mean" or "Tell me more about it." The researcher did not prompt the participants with leading questions or spell any words in the questions. Participants were not given any written instructions for this task; the task was explained beforehand by the researcher. Scores consisted of the number of correct responses. The principal researcher scored all participants to provide consistency in scoring.

For the Vocabulary subtest the test was divided into odd and even questions to produce two versions of the test, versions A and B, with 17 words to be defined in each version. The versions were counterbalanced so that every participant received a different version at pretest and posttest. The words to be defined became progressively more difficult from first to last. The researcher asked the participants "What is the meaning of the word ...?" The participants could take as much time as desired to answer (this was not a timed task). If a participant's answer was unclear or vague the researcher prompted the participant by saying "Tell me more about it" or "Explain what you mean" or some other neutral inquiry. The researcher did not prompt the participants with leading questions or hints. Answers were scored 0, 1, or 2 depending on the quality of the answer. Obviously wrong answers were scored 0. An answer that was not completely incorrect but showed a limited, imperfect understanding of the word was scored 1. An
answer which was obviously correct and showed a thorough understanding of the word was scored 2. The protocol gives numerous examples of 0, 1, and 2 point answers. The score for the task was computed by adding together the scores for each of the words. The principal researcher scored all responses for all participants to provide consistency of scoring. No written instructions were given to participants; the task was explained beforehand by the researcher.

The four tests of Fluid Intelligence were the manual Stroop task, the automated Stroop task, a precued reaction time task, and a pattern comparison task (Salthouse & Babcock, 1991). The four tests of Fluid Intelligence were counterbalanced among participants so that participants performed the tests in different order at pretest and posttest.

For the manual Stroop task participants were told to read aloud various words and colors for periods of 45 seconds. The task consisted of three sheets of paper. On the first page the words “red,” “green,” and “blue” were printed in black ink in random order in five columns of 20 words (100 words on the page). The participants simply read the words starting at the top left corner of the page and proceeding down the first column, then to the top of the second column, and so on until the 45 seconds had lapsed. If a participant read all the words on the page (got to the bottom of the last column) before time had expired he/she simply returned to the top left corner and continued reading. The second page contained groups of four Xs; each group of four Xs was printed in either red ink or green ink or blue ink. This page had five columns of 20 groups of Xs for 100 groups of Xs arranged in random order. The participants had to read aloud the color of the ink in which the groups of Xs were printed. As before, if a participant reached the
bottom of the last column he/she simply returned to the top left corner of the page and continued reading. Participants read the colors aloud for 45 seconds. On the third page were five columns of 20 words per column. The words were "red," "green," and "blue" printed in the ink colors of red, green, and blue, but the color of the ink did not match the meaning of the word. The word "green" was printed in either red or blue ink, the word "red" was printed in either green or blue ink, and the word "blue" was printed in either red or green ink. These words were arranged in random order on the page. The participants had to say aloud the color of the ink, not the meaning of the word. Again they were given 45 seconds to perform this task. For all three pages of this task participants were instructed that if they misspoke they were to correct themselves and continue. They were told to proceed as quickly as they could and still be accurate. Each page was scored separately, and scores were the number of responses on each page. In addition, the scores for all three pages were added together to produce a fourth score, the total score for the whole task. Participants were given written instructions prior to the task, a copy of which is included in Appendix D. After the participants had read the instructions the researcher went over the instructions with the participants to ensure understanding.

For the automated Stroop task participants responded to words presented in different colors of ink on a computer screen. The participants sat at a keyboard in front of a computer screen. For each trial a beep was sounded two seconds before the stimulus was presented, to alert the participants that the stimulus was about to appear. Next an "X" appeared in the center of the screen to indicate where the stimulus would appear. Then the stimulus was presented for 500 ms. There were four different stimuli, presented in
random order. The stimuli were the word "red" printed in red ink, the word "red" printed in green ink, the word "green" printed in red ink, and the word "green" printed in green ink. A piece of red tape was placed on the "f" key and a piece of green tape was placed on the "j" key on the keyboard. The participants responded to the stimulus by pressing the same color key as the color of the ink (the participants responded to the color of the ink, not the meaning of the word). For example, if the stimulus was the word "red" printed in green ink the correct response was the pressing of the green key. Participants were instructed to respond as quickly as possible while still giving an accurate response. Reaction time was measured in milliseconds. A copy of the written instructions provided to each participant is included at Appendix E. The participants read the printed instructions and then the researcher went over the instructions with the participants to insure they understood the task. The researcher also observed the first few trials to ensure the participants were following instructions. There were two versions of this task and the versions were counterbalanced so that participants received one version at pretest and the other version at posttest. Participants' scores were the means of the correct responses.

For the precued reaction time task participants were seated at a keyboard in front of a computer screen. On the screen there were four circles labeled "d," "f," "j," and "k." Participants were instructed to place the first two fingers of their left hand on the "d" and "f" keys and to place the first two fingers of their right hand on the "j" and "k" keys. As soon as they saw one of the four circles light up they were to press the corresponding key as quickly as possible while still being accurate. For example, if the "f" circle lit up the correct response was to press the "f" key. Essentially this was a reaction time task, with
reaction time measured in ms, but there were three versions of the task. For each version the participants were given cues as to which circle might light up. The cues were straight horizontal lines above the circles. On the first version the participants were given 10 trials with a line (the cue) placed randomly over only one of the circles, indicating that particular circle would be the one lighting up. This version was a simple reaction time task where the participants knew in advance which circle would light up and they had only to wait for the circle to light up and then respond as quickly as they could. On the second version the participants were given 10 trials where a line (the cue) was placed randomly over two of the four circles, which told the participants that one of those two precued circles would light up. This version of the task was a choice reaction time task where the participants had to choose the correct stimulus from two possible stimuli. On the third version of this task the participants were presented with 10 trials with lines (the cues) over all four circles, which told them that any one of the four circles could light up. This fourth version was again a choice reaction time task but the participants had to choose from among four possible stimuli. A copy of the written instructions given to the participants is included in Appendix F. Participants read the printed instructions and then the researcher went over the instructions to ensure the participants understood the task. The researcher also observed the first few trials to ensure the participants were following instructions. Each of the three versions of the task was scored separately. Scores were the mean reaction times in milliseconds for the correct responses for each of the three versions of the task.

For the pattern comparison task the participants were given a two-page handout: the top page contained the instructions and three practice trials, and the bottom page
contained the task. The task consisted of two squares containing meaningless figures or
symbols with a straight line separating the two squares. If the figures in the two squares
were identical then the participant was to write an “S” (for “same”) on the line between
the squares, and if the figures in the two squares differed in any way the participant was
to write a “D” (for “different”) on the line between the squares. The second page
contained 30 trials (30 sets of two squares containing figures with a line between the
squares), and the participants were given 45 seconds to complete as many trials as
possible while still being accurate. The participants read the instructions and completed
the three practice trials on the top page, and the researcher went over the instructions with
the participants to ensure they understood the instructions. The researcher told the
participants when to turn over the top page and begin the task, then the researcher timed
the task and told the participants when to stop. There were two versions of this task and
the versions were counterbalanced so that each participant received one version at pretest
and the other version at posttest. The score was the number of correct responses.

At both pretest and posttest the four tests of Fluid Intelligence were administered first
followed by the two tests of Crystallized Intelligence. This was done because the four
fluid tests all have a speed component. The manual Stroop and the pattern comparison
tasks are timed tasks, and the automated Stroop and the precued reaction time tasks both
measure reaction time. Since the tests of Fluid Intelligence have speed components it
was logical to assume that they were more likely to be impacted by fatigue than the tests
of Crystallized Intelligence which have no speed component. Furthermore, the tests of
Crystallized Intelligence were not compared to norms to assess intelligence; only the
change in scores between pretest and posttest was analyzed to determine if any
significant change in performance had occurred. Finally, since tests of Crystallized Intelligence measured cognitive abilities different from the abilities measured by tests of Fluid Intelligence, it was very unlikely that any carryover effects from one type of test to the other occurred.

The two groups differed in the level of difficulty and scheduling of the intervention task. The participants in both groups worked crossword puzzles for 4 hours per week for 8 weeks for a total of 32 hours of intervention. All participants were instructed to answer as many clues as possible using the dictionary provided and their own knowledge, and when they were unable to answer any more clues to proceed to the next puzzle in the book. All participants in both groups began working easy (beginner) puzzles. At the end of the second, fifth, and eighth weeks the researcher called each participant and asked about the participant’s progress and compliance with instructions. The participants in the Constant Group worked easy (beginner) puzzles throughout the eight weeks of the study. The participants in the Dynamic Group worked easy (beginner) puzzles for the first 2 weeks, medium difficulty puzzles for the next 3 weeks, and hard (expert) puzzles for the final 3 weeks of the intervention. Every participant was supplied with a sufficient number of puzzles to ensure that no puzzle was worked a second time. Every participant was given a crossword puzzle dictionary and was instructed to answer the clues using only the dictionary provided and personal knowledge. After the pretest every participant was given a sheet of written instructions specific to the participant’s group, and the researcher reviewed the instructions with each participant. Copies of the group instructions are included in Appendix G. When participants returned for the posttests the puzzle books and dictionaries were retrieved and reviewed to confirm compliance with
instructions. All testing of dependent measures was conducted at the Motor Behavior Laboratory, University of Nevada, Las Vegas.
CHAPTER 4

RESULTS

The information and vocabulary tests were scored in accordance with the prescribed protocol for the WAIS-R as described in the previous chapter. Reaction time scores on the precued reaction time task and the automated Stroop task were calculated in milliseconds for each participant. The pattern comparison and manual Stroop tasks were scored for the number of correct responses as described in the previous chapter.

Six participants failed to complete the study. Subject mortality was differential between groups, leaving the Constant Group with 4 participants and the Dynamic Group with 7 participants. At the completion of the study the Constant Group had a mean age of 68.8 with a standard deviation of 4.79 and the Dynamic Group had a mean age of 70.7 with a standard deviation of 3.2. The mean ages of the two groups still were not significantly different. \( F(1,9) < 1, \ p = .43 \).

At the conclusion of the study the scores for each dependent measure were analyzed using a 2 [Group (Constant and Dynamic)] x 2 [Test (Pretest and Posttest)] Analysis of Covariance (ANCOVA) with repeated measures on the last factor and with age as the covariate. An ANCOVA was used to partial out the variance in scores due to age and give a purer measure of the effect of the intervention on the dependent variables. Alpha
was set at .05. Since 11 ANCOVAs were performed in this study alpha was adjusted using the Bonferroni correction by dividing .05 by 11 to get an alpha of .005.

For the information task the number of correct responses for each participant at both pretest and posttest were analyzed. The Constant Group showed slight improvement in correct response scores from pretest to posttest, while the Dynamic Group exhibited a slight decline. The Constant Group pretest mean was 10 with a standard deviation of 1.2 and the posttest mean 10.3 with a standard deviation of 2.2. The Dynamic Group mean was 11.3 with a standard deviation of 2 and the posttest mean was 10.9 with a standard deviation of 1.9. There were no main effects or interactions. Group means are graphed in Appendix H, Figure 1.

For the Vocabulary task the scores of each participant on both the pretest and the posttest were analyzed. Both groups showed slight improvement in response scores from pretest to posttest. The Constant Group pretest mean was 24 with a standard deviation of 4.6 and the posttest mean was 26.3 with a standard deviation of 2.9. The Dynamic Group pretest mean was 28 with a standard deviation of 3.4 and the posttest mean was 29.1 with a standard deviation of 3.8. Once again there were no main effects or interactions. Group means are graphed in Appendix H, Figure 2.

For the pattern comparison task the number of correct responses for each participant on both the pretest and the posttest were analyzed. Both groups again showed some improvement in correct response scores from pretest to posttest. The Constant Group pretest mean was 12 with a standard deviation of 3.2 and the posttest mean was 14.5 with a standard deviation of 3.4.

The Dynamic Group pretest mean was 12.1 with a standard deviation of 3 and the
posttest mean was 14.1 with a standard deviation of 2.3. There were no main effects or interactions. Group means are graphed in Appendix H, Figure 3.

For the precued reaction time task, mean reaction times for each participant on both the pretest and the posttest were analyzed; data for the one choice, two choices, and four choices conditions were analyzed separately. For the one choice condition both groups improved their reaction time scores from pretest to posttest. The Constant Group pretest mean was 486 ms with a standard deviation of 29 and the posttest mean was 390 ms with a standard deviation of 167; the Dynamic Group pretest mean was 1108 ms with a standard deviation of 2026 and the posttest mean was 340 with a standard deviation of 97. There were no main effects or interactions. However, it should be noted that no score was excluded unless it exceeded the a priori exclusion limit of two standard deviations from the mean. One subject produced anomalous data causing the large standard deviation for the Dynamic Group pretest scores. This particular participant had reaction times of 20650 and 22189 ms. If these two data points are removed from the data set the Dynamic Group pretest mean would be 406 ms with a standard deviation of 109 ms. For the two choices condition both groups improved their reaction time scores from pretest to posttest. The Constant Group pretest mean was 511 ms with a standard deviation of 115 and the posttest mean was 499 ms with a standard deviation of 107; the Dynamic Group pretest mean was 586 ms with a standard deviation of 226 and the posttest mean was 461 ms with a standard deviation of 118. There were no main effects or interactions. For the four choices condition the Constant Group exhibited a slight increase in reaction time scores from pretest to posttest while the Dynamic Group improved its reaction time scores from pretest to posttest. The Constant Group pretest
mean was 611 ms with a standard deviation of 194 and the posttest mean was 617 ms with a standard deviation of 230; the Dynamic Group pretest mean was 585 ms with a standard deviation of 162 and the posttest mean was 542 ms with a standard deviation of 65. There were no main effects or interactions. Mean reaction time scores for all three conditions of the precued reaction time task are graphed in Appendix H. Figures 4, 5, and 6.

For the manual Stroop task there were three conditions: word, color, and colorword. The scores for the number of correct responses by each participant on both the pretests and the posttest were analyzed separately. A fourth score composed of the sum of the scores for the three conditions was computed for each participant and called the total score for the task, and the total scores for each participant were also analyzed. For the word condition both groups improved their scores from pretest to posttest. The Constant Group pretest mean was 98 with a standard deviation of 6.1 and the posttest mean was 105.3 with a standard deviation of 5; the Dynamic Group pretest mean was 105.7 with a standard deviation of 10.2 and the posttest mean was 109.7 with a standard deviation of 12.2. There were no main effects or interactions. For the color condition both groups improved their scores from pretest to posttest. The Constant Group pretest mean was 64.3 with a standard deviation of 10.1 and the posttest mean was 73.8 with a standard deviation of 8.8; the Dynamic Group pretest mean was 69 with a standard deviation of 8.8 and the posttest mean was 74.6 with a standard deviation of 10.1. There were no main effects or interactions. For the colorword condition and the total score the data from one participant could not be used because the participant failed to follow directions and did not perform the colorword condition correctly; the scores of the other 10
participants (three in the Constant Condition and seven in the Dynamic condition) were analyzed. For the colorword condition both groups showed improvement from pretest to posttest. The Constant Group pretest mean was 37 with a standard deviation of 3.5 and the posttest mean was 41.3 with a standard deviation of 5.5; the Dynamic Group pretest mean was 36.7 with a standard deviation of 7.3 and the posttest mean was 40.1 with a standard deviation of 8.8. There were no main effects or interactions. For the total scores both groups showed improvement from pretest to posttest. The Constant Group pretest mean was 196.7 with a standard deviation of 12.1 and the posttest mean was 216 with a standard deviation of 8.7; the Dynamic Group pretest mean was 211.4 with a standard deviation of 22.1 and the posttest mean was 224.4 with a standard deviation of 24.4. There were no main effects or interactions. The group means for all three conditions and the total scores are graphed in Appendix H. Figures 7, 8, 9, and 10.

For the automated Stroop task scores for all incorrect responses (that is, the response was “red” when it should have been “green” or “green” when it should have been “red”) and all response errors (that is, those trials with a reaction time of zero because no response was given within the allotted time) were excluded. For the correct responses all reaction time scores more than two standard deviations above or below the mean were excluded because it was presumed that such scores were the result of either anticipation (those scores more than two standard deviations below the mean) or inattention (those scores more than two standard deviations above the mean). For the valid correct responses the mean reaction times of each participant on both the pretest and the posttest were analyzed. The reaction time scores of both groups showed improvement from pretest to posttest. The Constant Group pretest mean was 847 ms with a standard
deviation of 238 and the posttest mean was 683 ms with a standard deviation of 73; the Dynamic Group pretest mean was 649 ms with a standard deviation of 129 and the posttest mean was 623 ms with a standard deviation of 120. There were no main effects or interactions. Group means are graphed in Appendix H, Figure 11.

Data for all dependent measures are arranged in a table of data contained in Appendix 1.
CHAPTER 5

DISCUSSION AND RECOMMENDATIONS

Discussion

This study was designed to determine the effect of a general intervention program on two tests of Crystallized Intelligence and four tests of Fluid Intelligence. Participants without prior experience working crossword puzzles were asked to work crossword puzzles for a total of 32 hours over 8 weeks. The research hypotheses were that this lengthy and demanding cognitive intervention would impact the participants' general cognitive ability and improve cognitive functioning, and that varying the difficulty of the intervention task would produce a differential impact on general cognitive ability. In general the results did not support the research hypotheses. On none of the six dependent measures did the results reach statistical significance.

Although the research hypotheses were not supported by statistically significant results, the trends apparent in the data are encouraging. A close examination of the data reveals that the intervention task may have influenced the cognitive performance of the participants. On the information task the Constant Group improved its performance from pretest to posttest, but the Dynamic Group showed a slight decline in performance. On
the vocabulary task both groups improved performance from pretest to posttest. On the pattern comparison task both groups again displayed improvement from pretest to posttest. On the precued reaction time task, for the one choice and two choices conditions both groups showed improved performance from pretest to posttest; for the four choices condition the Constant Group exhibited a slight decline in performance while the Dynamic Group improved from pretest to posttest. On the manual Stroop task, for all three conditions (word, color, and colorword) plus the total score, both groups exhibited definite improvement from pretest to posttest. Finally, on the automated Stroop task, for the correct responses both groups improved from pretest to posttest (as discussed above, the Constant Group improved much more than the Dynamic Group). The data does not show a clear indication that either group performed better than the other group across all dependent measures (the data does not indicate a preference for either the constant or dynamic scheduling of the intervention task).

In general the data suggest improved cognitive performance. On 20 of the 22 measures the means moved from pretest to posttest in the direction of improved performance. This can be seen by examining the graphs in Appendix H and the table of data in Appendix I. The group means suggest a pattern of improved performance over the course of the study. This is encouraging because if the intervention had not impacted general cognitive abilities then the most probable result would have been a random fluctuation in group means (an equal number of means showing improvement and decline) or a pattern showing that most or all of the means moved in the direction of declining performance decline over the duration of the study (cognitive performance in older adults generally declines over time). The fact that most dependent measures
showed not a decline but an improvement is considered a positive outcome for this study.

The lack of statistical significance in the data analysis may have been due to the low number of participants who completed the study (low N). Only 11 participants completed this study, 4 in the Constant Group and 7 in the Dynamic Group. Low N reduced the power of the statistical analyses and made it difficult to detect differences between the groups and among the tests, even if such differences existed.

Limitations

This study did not employ a control group. When the study was being designed the use of a control group was considered, but it was decided that a control group would not be necessary. Past research provides absolutely no reason to expect that cognitive performance in older adults will improve over time without any intervention. In addition, for the Dynamic Group the intervention task difficulty was increased over the course of the study to counter any possible practice effects on the intervention task. Finally, it was anticipated that it would be difficult to recruit participants and adding a third group would have reduced the number of participants in each group even further. Admittedly the lack of a control group weakens this study, but for the reasons given above it seems very unlikely that the absence of a control group had any real effect on the outcome.

One other weakness of this study is the possible lack of external validity. The results may not generalize to the total population of older adults. The sample obtained for this study may not have been representative of the general older adult population. Participants were not formally questioned about their habits and activities, but from general conversations with the participants it was clear that they all were very active people. Although all of them professed to be retired, all of them indicated that they were
very busy with part-time jobs, volunteer work, hobbies, and other kinds of activities. The active life style of the participants may not be typical of the lives of most older adults. Since active lifestyles generally accompany higher cognitive functioning in older adults the sample used in this study may have been biased towards higher cognitive performance.

Recommendations

It proved exceedingly difficult to recruit participants for this study. The requirement that participants have no significant prior experience working crossword puzzles disqualified many potential participants who otherwise would have volunteered for this study. The intervention task was lengthy (8 weeks) and required much time (32 hours). The arduous nature of the intervention discouraged many from participating and contributed to the dropout of those participants who started but failed to complete the study. The researcher asked those who left the study their reasons for quitting. One participant left the study before completion because of the illness of her spouse. The other dropouts said they quit because either they found the intervention task too difficult or they simply lost interest in doing crossword puzzles (did not enjoy puzzling). Of the participants who did complete the study, most said they did not enjoy working crossword puzzles and they persevered only because of a sense of duty, although a few discovered that they did enjoy working crossword puzzles and said they might continue to work puzzles in the future.

Participants were asked to perform a new and (for some) difficult task over a long period of time. Because of the lack of research funds it was not possible to pay each participant an amount of money that would have been sufficient to persuade anyone to
participate in this study. Those who completed this study did so because they wished to make a contribution to science, not for monetary gain. To reward at least one of the participants the lottery described previously was devised, but no participant indicated that the possibility of winning the lottery influenced his or her decision to participate. At the conclusion of the study the lottery was held and one of the participants was awarded the $100.00 prize.

Because the trends in the data suggest that the intervention task may have influenced general cognitive abilities it is recommended that efforts be made to recruit more participants and continue this study. Originally the goal was to recruit 50 participants, 25 for each of the two groups. If this goal could be met the larger number of participants (larger N) would produce greater statistical power and might reveal statistically significant differences between groups or among dependent measures. To recruit the desired number of participants it is recommended that funding be sought so that each participant could be paid a sum that would be fair compensation for the amount of time and effort required by this study. It is also recommended that efforts be made to recruit participants with less active as well as more active lifestyles; this would increase the external validity of this study.

If a sufficient number of participants could be recruited and if results were to achieve statistical significance then the research hypothesis would be supported. Statistically significant findings would suggest a transfer effect, that training on one cognitive task had impacted several cognitive abilities previously thought to be unrelated. Such results would also support the resource approach to cognition. This would encourage future research designed to search for other cognitive tasks that would impact g. The results of
this study are sufficiently promising to justify the continued collection of data if suitable participants can be recruited.
APPENDIX A

SCREENING QUESTIONNAIRE
Moderation of Age-related Cognitive Decline in Older Adults

Personal Information and Health Status Questionnaire

Name:

Local Address:

Local Telephone Number:

Age:

Highest Level of formal education you have completed:

- High School
- Associate's Degree
- Bachelor's Degree
- Master's Degree
- Doctorate Degree
- Other

Have you been diagnosed with any of the following medical conditions (if yes, please explain on the back of this form):

- Any learning disability
- Any psychological disorder or illness
- Any head injury that resulted in loss of consciousness for more than 5 minutes
- Any injury or disorder that impairs your hand or finger movements
- Any vision problem
- Do you wear eyeglasses or contact lenses?

Please rate your prior experience with computers:

- No experience
- Limited experience
- Moderate experience
- Extensive experience

Do you have any prior experience working crossword puzzles? If yes, please tell how often you work them and over what period of time you have been doing them.

How would you rate your level of expertise as a crossword puzzler?
University of Nevada Las Vegas. Department of Kinesiology
Motor Behavior Laboratory

1. The principal investigator for this study is Joseph F. Boetcher who is a graduate student at UNLV, Department of Kinesiology.

2. You are invited to participate in a study of human motor behavior and cognition.

3. The purpose of this study is to explore the relationship between cognition and aging. A non-invasive intervention will be used to attempt to moderate the effects of age on cognition. The study will last about eight weeks. Participants will be administered six psychometric tests at the beginning and again at the end of the study; each testing session will last about one hour. In addition, participants will work crossword puzzles at home for four hours per week for the eight weeks of the study.

4. There are no known risks or discomforts associated with this research. This information is based on a large body of experience with the same or similar tasks. Individual participants may or may not experience improved cognitive functioning as a result of this study. Even if no individual benefit occurs, participation will help increase the sum of scientific knowledge on cognitive aging.

5. Participants who complete this study will receive one chance in a drawing to win $100.00.

6. Any personal information that is obtained in the course of this study will remain confidential. The results of this study may be published in scientific journals, but only statistical data will be published and no individual participant will be identified.

7. If you have any questions or concerns about this research, or if you wish information about the rights of research subjects, you may contact the UNLV Office for the Protection of Research Subjects at 702-895-2794, or the principal investigator at 702-895-1241.

8. Participation in this study is voluntary and you may withdraw from participation at any time. Your decision whether or not to participate or to withdraw will not prejudice your future relations with the University of Nevada Las Vegas.

Your Signature below indicates that you have read and understood the above information, and that you are freely consenting to participate in this study.

_____________________________  ________________________
Printed Name                                Date

_____________________________
Signature

_____________________________
Participant Number
And Researcher
APPENDIX C

OFFICE FOR THE PROTECTION OF RESEARCH SUBJECTS APPROVAL
DATE: April 28, 1998

TO: Joseph F. Boetcher (KIN)
     M/S: 3034

FROM: Lawrence Golding
       Chair, Biomedical Sciences Committee
       UNLV Institutional Review Board

RE: Status of Human Subject Protocol entitled:
"Moderation of Age-related Cognitive Decline in Older Adults"

OSP #504s0498-015b

This memorandum is official notification that the protocol for
the project referenced above has been approved by the Biomedical
Sciences Committee of the Institutional Review Board. This
approval is approved for a period of one year from the date of
this notification, and work on the project may proceed.

Should the use of human subjects described in this protocol
continue beyond a year from the date of this notification, it
will be necessary to request an extension.

If you have any questions or require any assistance, please
Marsha Green at 895-1357.

cc: OSP File
APPENDIX D

MANUAL STROOP PARTICIPANT INSTRUCTIONS
Manual Stroop Instructions

The task you are about to perform will require you to read aloud various words and colors for a duration of 45 seconds. On the first page your goal will be to read aloud as many words as possible in the time allotted. When the lab assistant tells you to begin, start at the top left of the page and read down until you come to the end of the column, then move up to the top of the next column to the right and continue reading aloud. Continue reading aloud down the columns until told to stop. If you reach the bottom of the last column return to the top of the first column and continue reading. At the end of 45 seconds the lab assistant will say "stop" and you will stop reading aloud. On the second page you will see X's printed in different colors: your goal is to say aloud the names of as many colors as possible in the time allotted. Again the lab assistant will tell you when to begin and when to stop, and you will begin at the top left of the page and read down the first column, then move to the top of the next column to the right, until told to stop. On the third and last page you will see words written in different colors of ink. Your goal will be to say aloud the color of the ink the word is written in. As before, begin reading at the top left corner and progress down the first column, then go to the top of the next column to the right and continue until the lab assistant tells you to stop. The lab assistant will go over these instructions with you before you begin.

If you have any questions please ask the lab assistant. Thank you for participating in this study.
APPENDIX E

AUTOMATED STROOP PARTICIPANT INSTRUCTIONS
Automated Stroop Task Instructions

The task which you are about to perform will require you to respond to words that appear in different colors of ink. You will respond by pressing colored keys on a keyboard. The words will be written in different colors of ink on a computer screen. The word **RED** will be written in either red ink or green ink, and the word **GREEN** will be written in either red ink or green ink. Your goal will be to respond to the color of the ink the word is written in by pressing the same colored key on the keyboard. For example, if the words "RED" appears written in green ink, you would respond by hitting the green key on the keyboard. Please respond as quickly as possible. The lab assistant will provide further instructions prior to the beginning of the experiment. If you have any questions please ask the lab assistant before you begin. Thank you for participating in this study.
Precued Reaction Time Task Instructions

The task you are about to perform will require you to press a key on a keyboard as quickly as possible after a light appears on the screen. You will place your left index finger on the “f” key, your left middle finger on the “d” key, your right index finger on the “j” key, and your right middle finger on the “k” key.

On the screen you will see four circles labeled “d,” “f,” “j,” and “k.” When a light comes on in one of these circles you are to press the corresponding key as quickly as you can. For example, if the “f” circle light comes on you are to press the “f” key with your left index finger as quickly as you can after the light comes on. In addition, you will see a horizontal line above some of the circles before any light comes on; these horizontal lines are cues to alert you to the circles that might light up. Sometimes you will see a line above only one of the four circles: this tells you that that particular circle is the circle that will light up, and you will know even before the light comes on which key you should press (but do not press the key until the light comes on). Sometimes you will see lines above two of the four circles: this alerts you that either of those two circles will light up, and you will know before any light comes on that you will have to choose between either of those two keys when one of the circles lights up. Finally, sometimes you will see lines above all four circles; this tells you that any of the four circles may light up and you will have to choose from among all four keys to press the correct key when one of the circles lights up.

Regardless of how many of the circles have lines above them, only one circle will light up and when it does you are to press the key that corresponds to that circle as quickly as you can and still select the correct key. The lab assistant will go over these instructions with you before you begin. If you have any questions please ask the lab assistant. Thank you for participating in this study.
APPENDIX G

CONSTANT AND DYNAMIC GROUP INSTRUCTIONS
Instructions for Members of the Constant Group

After you complete the pretests you will be given crossword puzzle books and a crossword puzzle dictionary. The crossword puzzle book contains puzzles rated as easy, medium, and hard by the publisher. **You are to work only those puzzles rated easy. Do not work any of the medium or hard puzzles. Work the puzzles for four hours per week for the next eight weeks.** You may work the puzzles at home on your own time whenever it is convenient for you, but please adhere to the schedule of four hours per week for the next eight weeks. Do not work any puzzles except those provided to you by the experimenter. If you run out of puzzles please call the experimenter at 341-6898, and he will provide you with more puzzles. Do not rework any puzzles you have already worked. Do not ask anyone for help in working these puzzles; rely only on your own knowledge and ability. You may use the crossword puzzle dictionary to assist you in working the puzzles, but do not consult other dictionaries or resource books. When you have answered all the clues you can on a puzzle, go on to the next puzzle. The experimenter will call you after two weeks, five weeks, and eight weeks to see how you are doing and if you have any questions or problems. After eight weeks of working crossword puzzles you will return to the lab and be posttested; please bring the crossword puzzle books and dictionary to the lab with you when you return. The experimenter will go over these instructions with you. If you have any questions please ask the experimenter. Thank you for participating in this study.
Instructions for Members of the Dynamic Group

After you complete the pretests you will be given crossword puzzle books and a crossword puzzle dictionary. The crossword puzzle books contain puzzles rated by the publisher as easy, medium, and hard. **You are to work puzzles rated easy for two weeks. At the end of two weeks stop working the easy puzzles and start working the medium puzzles. Work medium puzzles for the next three weeks, then stop working medium puzzles and begin working hard puzzles. Work hard puzzles for the next three weeks.** You are to work crossword puzzles for four hours per week for the eight week duration of the study. Thus you will be working crossword puzzles for four hours per week for a total of eight weeks: two weeks of easy puzzles, three weeks of medium puzzles, and three weeks of hard puzzles. You may work the puzzles at home on your own time whenever it is convenient for you, but please adhere to the schedule stated above. Do not work any puzzles except those provided to you by the experimenter. If you run out of puzzles please call the experimenter at 341-6898, and he will provide you with more puzzles. Do not rework puzzles you have already worked. Do not ask anyone for help in working the puzzles; rely only on your own knowledge and ability. You may use the crossword puzzle dictionary to assist you in working the puzzles, but do not consult other dictionaries or resource books.

When you have answered all the clues you can on a puzzle, go on to the next puzzle. The experimenter will call you after two weeks, five weeks, and eight weeks to see how you are doing and if you are having any problems, and to remind you to start working the medium or hard puzzles. After eight weeks of working crossword puzzles you will return to the lab and be posttested; please bring the crossword puzzle books and dictionary to the lab with you when you return. The experimenter will go over these instructions with you. If you have any questions please ask the experimenter. Thank you for participating in this study.
Figure 1
Figure 2
Pattern Comparison

Pretest Posttest

Test

Constant Dynamic

Figure 3
Figure 4

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Figure 5
Figure 6
Figure 7
Figure 8
Figure 9
Figure 10
Automated Stroop - Correct Responses

![Graph showing reaction time for pretest and posttest with static and dynamic tests.](image)

Figure 11

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APPENDIX I

TABLE OF DATA
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<th>Dynamic</th>
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<td>511 (115)</td>
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<td><strong>Precued4</strong></td>
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</tr>
<tr>
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Mean (Standard Deviation)

Pat. Com. = Pattern Comparison Task
Precued1 = Precued Reaction Time Task. 1 Choice Condition
Precued2 = Precued Reaction Time Task. 2 Choices Condition
Precued4 = Precued Reaction Time Task. 4 Choices Condition
MSWord = Manual Stroop Task. Word Condition
MSColor = Manual Stroop Task. Color Condition
MSColorword = Manual Stroop Task. Colorword Condition
MSTotal = Manual Stroop Task. Total Score
Auto. Stroop = Automated Stroop Task. Correct Responses
REFERENCES


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