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Use it or Lose it? What Predicts Age-Related Declines in Cognitive Performance in Elderly Adults?

Katherine Midkiff
Grand Valley State University

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Katherine Midkiff
McNair Scholar

Bradley J. Morris, Ph.D.
Faculty Mentor

ABSTRACT
Psychologists have suggested two possible causes of declines in cognitive performance with age: declines in cognitive capacity (e.g., working memory), and the level of stimulation in their environments. Fourteen college students (mean age=21 years, SD=1.65), seven middle-aged (40-59, mean age=51, SD=4.8), and five elderly (60+, mean age=74.8, SD=8.3) participants completed a series of assessments including simple and complex measures of processing and reasoning and assessments of cognitive stimulation. The results indicated that working memory declines with age and that these declines predicted performance on complex reasoning tasks while cognitive stimulation was unrelated to performance.

Introduction
Psychologists have long documented a general decline in cognitive performance during the adult aging process (Salthouse, 1996). Recent research has suggested two possible causes for this decline: (1) decline is an inevitable factor in aging or (2) decline is a result of cognitive inactivity (Meiser & Klauer, 1999; Salthouse, Berish, & Miles, 2002). The first hypothesis suggests that with aging comes a decline in cognitive functioning due to a reduction in processing resources available to the reasoner. The second hypothesis suggests cognitive activity will stave off the effects of aging and subsequently maintain cognitive functioning.

Declines in Capacity and Speed
This general decline in the performance of adults may be explained by the cognitive load theory (CLT) (Paas, Camp, & Rikers, 2001). CLT suggests that the limited capacity for reasoning decreases with age and that this decrease is directly related to declines in reasoning and problem solving in later years. Pass et al. (2001) demonstrated a consistent decline in working memory (WM), a system that momentarily stores information available for ongoing cognitive processes capacity with age (Oberauer, 2001).

There are three components of working-memory: (1) the phonological loop, (2) the visuo-spatial scratch pad, and (3) the central executive. Each of these components represents a resource that can be used for processing of different tasks. The phonological loop specializes in momentary storing and rehearsal of serial speech-based codes, as in reciting a phone number until the phone number is dialed. The visuo-spatial component processes information that is coded visually and spatially. The central executive function is the component that acts as a general processing agent for all else that the other two do not cover. Central executive function also directs all conscious responsibilities, all resource coordinating of activities, and monitors task performance. This function can also donate processing capacity to other functions when the load reaches capacity (Conners, Carr, & Willis, 1998). The phonological loop and visio-spatial sketchpad are used for simple cognitive tasks while the central executive is recruited for complex tasks.

Such a decline in WM capacity should reduce an individual's capacity for reasoning. These declines are found to be more apparent when the task places a greater amount of load on the working memory. When presented with a simple task, the phonological loop is recruited for momentary recitation. When a task requires additional processing, the central executive component of the working memory donates additional processing capacity. It has been suggested that it is a decline in executive functioning that declines with age (Conners et al., 1998). Furthermore, this slowing of information processing appears to begin as early as 40 years old (Myerson, Hale, Hirschman, & Hansen, 1989). The notion of a slowed working memory appears to be linked to an individual's capacity to reason and problem solve.

Capacity, Performance, and Complexity

An additional factor in cognitive performance is the complexity of the problem to be solved (Halford, 1993). The more complex the problem, the more processing resources are required for its solution. Thus, a decline in resources reduces the likelihood of solving complex problems (Halford). Complexity is a measure of the central executive component of working memory and is likely related to performance on complex reasoning tasks.

Older adults show declines in the efficient use of WM capacity and in cognitive tasks such as mental rotation, a simple cognitive task in which subjects are shown a series of letters that have been rotated 45, 90, or 180 degrees. In this task, Roberson, Palmer, and Gomez (1987) found that older adult performance decreased as the degree of rotation increased. Salthouse, Berish, and Miles (2002) found that there is an age-related decline in reasoning capacity. This decline in capacity (i.e., processing space) was a major predictor of age-complexity effects. The authors note that this capacity for reasoning was affected in a number of cognitive tasks including those that are cognitively complex and cognitive tasks that were simple.

One major limitation is that although many studies have examined simple cognitive tasks (e.g., letter rotation), few have examined simple and complex tasks in the same experiment. One type of complex task is logical reasoning. Logical reasoning (e.g., syllogistic reasoning) draws on the central executive in the integration of semantic and syntactic information (Johnson-Laird, 1999).

A second factor is processing speed. Processing speed is a factor in the efficient use of limited capacity in that the faster the processing speed, the more operations can be executed in the same amount of space (Kail, 2000). Slow processing speed has been associated with poor performance by children because they cannot complete the necessary components of the task in the allotted time (Kail & Hall, 1994). Processing speed increases throughout childhood and levels off in adulthood (Kail). Salthouse (1996) notes that there is a gradual speed and efficiency decline with age. Studies by Cepeda (2001) have shown that individuals between the ages of 71-85 show some difficulty in task inertia, that is, the activation of the stimulus-response rule after a change of task that required a reconfiguration of the cognitive system. This preparation increases the response-time and thus increases the amount of errors especially in the elderly population (Yeung & Monsell, 2003).

Verheghen et al. (2002) found that the slowing of processing time may result in retention intervals being lengthened and may increase the likelihood that stored information will decay. According to the authors, this means that the information-processing mechanism (i.e. processing stream) shows age-related deficits. The authors go on to note that those memory dependent tasks should show a large amount of deficits and can result in a poor performance on cognitive tasks. Many researchers have studied this decline in processing speed.

For example, there is a marked decline in the performance of elderly participants on the Tower of Hanoi puzzle, a task that requires planning and inhibition, two factors that tax processing capacity and speed (Davis & Klebe, 2001). There is much research that has found in an elderly population a reduced ability to manipulate and organize information in the working memory (Campbell & Charness, 1990). The authors go on to note that declines can be the result of a general slowing in informational processing.

"Use it or Lose it"

There is a second explanation for this decline in cognitive performance in the elderly sometimes called "use it or lose it." This explanation suggests maintaining cognitive function can stave off cognitive decline. Without this maintenance, cognitive operations will begin to atrophy from disuse much like physiological structures (e.g., muscles) that are not used. Salthouse, Berish, and Miles (2002) found it conceivable that with increased age there is a decrease in engagement in cognitively demanding activities. Results are mixed as to whether engagements in cognitively stimulating activities are related to cognitive declines. Hultsch, Small, Dixon, and Roger (1999) note that older adults seem to have a reserve capacity that allows them to benefit from exposure to performance enhancing environments; furthermore, this exposure may, in fact, be able to predict a reversal of, or at least a maintenance, of cognitive levels.

Performance enhancing environments can be described in many ways, but for our purposes, we will follow Hultsch, Small, Dixon, and Roger (1999) who define a complex environment, or cognitive stimulus, as one with diverse stimuli that requires complex decision making, with ill-defined contingencies that appear to be in contradiction. These authors go on to explain that research suggests that there is a "use it or lose it" component on cognitive tasks and that performance can be moderated by an individual's exposure to complex stimulus in his/her environment.

The purpose of this project is to compare and investigate explanations for decline in cognitive performance due to aging. This will be accomplished by measuring factors in processing capacity and maintenance then comparing these to performance on several cognitive tasks.

We will measure activity levels and three elements of the capacity hypothesis: (1) processing capacity (a measure of phonological working memory or simple capacity), (2) processing speed (a measure of the time to execute cognitive operations), and (3) processing space (a measure of the executive function of working memory or complex capacity). We will then measure simple (e.g., letter rotation) and complex (i.e., syllogistic reasoning) reasoning measures to determine which, if any, of the aforementioned factors best predicts performance.

Method

Subjects

Twenty six subjects from three groups took part in this experiment. The control group was made up of 14 young subjects (mean age=21 years, *SD*=1.65), seven middle age subjects (40-59, mean age=51, *SD*=4.8), and five elderly (60+, mean age=74.8, *SD*=8.3). The control group was recruited from Psychology 101 and Psychology 301 classes at Grand Valley State University; these participants were either given credit or extra credit for their participation. The middle-age and elderly participants were recruited from North Ottawa County Council on Aging and included members and patrons of the senior center. The age breakdown is consistent with mean ages of prior research conducted concerning working memory, on a wide age range of subjects (Myerson et al., 1989; Campbell & Charness, 1990).

Materials

There are three types of measurements in this project: (1) processing capacity, (2) cognitive maintenance, and (3) cognitive tasks. There are two measures of processing capacity: simple and complex. The Word-Span-Simple task (Daneman & Carpenter, 1980) used was the word span measurement. Each participant is presented with a random series of three-letter words at a rate of one per second. After the sequence is completed, the participant is asked to repeat the words in order. The word series range from three-word to nine-word combinations for 16 trials.

The complex task used was the Word-Span-Rhyme-New task (De Beni, Palladino, Pazzaglia, & Cornoldi, 1998). This is the same procedure as the word span with a few additions. The presented words are now two-letter words and after each word is presented, there is a second word presented at a delay. The participant is asked to decide if the second word rhymes with a target word, *blow*, and press a paginated button if the word rhymes with the target word or a second button if it does not. For each task, the subjects will be scored on span (number of words correctly recalled) and recall rate (how quickly they recalled words). These tasks were selected to provide a measure of verbal working-memory (Case, Kurland, & Goldberg, 1982).

Maintenance

Salthouse, Berish, and Miles (2002) have used the Activity Inventory and the 18-item version of the Need for Cognition (AINC) noting that it involves a range of cognitive tasks. Participants will also be asked their age, sex, and education level. The specific instructions for the AINC read, "rate how cognitively demanding you feel the activity is on a 5-point scale where 1=absolutely no cognitive demands (e.g. sleeping), 3=moderate cognitive demands (e.g. reading a newspaper), and 5=high cognitive demands (e.g. completing a tax form)" (p. 551).

Cognitive Tasks: Simple

Letter rotation

Roberson et al. (1987) note that the process of letter rotation is analogous to the process involved in the perception of the transformation of externally rotating objects. In this task, one letter is presented on the middle of a computer screen. They refer to this process as mental rotation. The authors go on to note that this mental rotation can be used as a measure of spatial representations and processing and to explain failures and successes in directional consistency in perceptual memory.

Trail making task (TMT).

Stuss et al. (2001) note that the TMT is one of the most widely accepted and sensitive general indicators of the presence of brain dysfunctions. TMT, Parts A and B require many cognitive processes including motor speed, visual search, and visual perception. Part B requires what the authors refer to as *cognitive alteration* and an ability to modify a plan of action, as well as maintaining two strains of thought concurrently. Salthouse et al. (2000), notes that the TMT is found to be of some interest because it seems to reflect aspects of executive functioning. Activity as factor in capacity: Hultsch, Small, Dixon, and Roger (1999), concluded in their research that there is a relationship between intellectual activity and cognitive function change. The TMT, Part A requires the participant to draw a line as quickly as possible joining the numbers 1-25. The test is arranged on an 8.5 x 11 inch page. Part B requires the participant to draw a line as quickly as possible joining the letters and numbers arranged on the same sized page (1-A-2-B-3…) (Stuss et al., 2001).

Cognitive Tasks: Complex

A syllogistic reasoning task was chosen to examine complex reasoning. Syllogisms (i.e., categorical syllogisms) have two premises and a conclusion. Subjects were given 32 syllogisms and were asked to evaluate the conclusion as either "valid" or "invalid." Syllogistic reasoning was chosen because it requires significant processing resources, drawing heavily on the central executive portion of working memory (Johnson-Laird, 1999).

Results

Of the 26 participants sampled in this study, 14 were used as a control group, seven were used as the middle-age group, and five were used as the elderly group. Because of an unequal distribution of age and generally small sample size, care should be taken evaluating cognitive declines across age groups.

Age and Reasoning Performance

There was a significant negative correlation between age and performance on the Word-Span-Simple task r (26)=-.508, p < .005 (see fig. 1), indicating that with increased age, there is a decline in working-memory performance. This negative correlation was also found between age and Word-Span-Rhyme-New task r (26)=-.531, p < .005, and again with increased age, there was a decreased working-memory performance.

The Letter Rotation task yielded unexpected results (see fig. 2 and 3). The control group was least likely to identify correctly whether the letter presented was in a mirrored or correct position. We believe that the control group pressed the paginated computer keys as quickly a possible to end the testing session resulting in their poor performance. This notion was supported with the examination of the latencies of the control group F (2, 23)=22, p<. 01. The control group took less time making their decisions on the position of the letter, which was shown by the latencies in milliseconds. As expected, the middle-age group outperformed the elderly group in correct responses F (2, 23)=8.9, p<. 05. Unexpectedly, the elderly group had shorter response latencies in decision-making than did the middle-age group, though this difference was not significant, F (2, 23) = .9, p>.10. We believe these results might be unrepresentative of the general population of elderly adults due to the small and uneven sample size.

The Trail Making task was analyzed with a 2 X 2 ANOVA, age of participant X mean number of correct executions, (see fig. 4). As expected, the control group outperformed both the middle-age group and the elderly group, F (2, 23)=10.1, p<. 01 on the mean number of correct executions of the Trail Making task. Again, we believe that these results would be more accurate with a larger number of participants in each age group.

The Logical Reasoning task revealed a negative correlation between age groups and the mean number of correct responses, r (26)=-.538, p < .005. There was a positive correlation between participant's performance on the Word-Span-Simple task and the mean number of correct responses on the Logical Reasoning task, r (27)=.559, p< .002. There was an even stronger positive correlation between the Word-Span-Ryhme-New task and the mean number of correct responses on the Logical Reasoning task, r (27)=.754, p < .001.

A linear regression was performed to examine the extent to which processing space and stimulation variables would predict performance on simple and complex tasks. Subject performance on the complex working memory task (i.e., Word-Span-Ryhme-New task) predicted 56% of the variance on the complex reasoning task (logical reasoning; b=.75, p< .001). There were no other significant relations between problem-solving performance and the amount of cognitive stimulation in one's environment (all p's >.10).

Discussion

What factors predict cognitive declines due to aging? Previous research had suggested two factors: decreases in capacity and cognitive inactivity. Our results support the capacity hypothesis but do not support the inactivity hypothesis. Our results demonstrate that the best predictor of performance on reasoning tasks was the measure of complex working memory, which is a measure of executive function. This measure was a particularly good predictor for complex tasks (i.e., logical reasoning). While our results did not support the inactivity hypothesis, we do not believe that these results necessarily provide evidence against the hypothesis. Many factors could have produced this null result, including low sample size, poor cognitive stimulation survey, and poor problem-solving measures. Moreover, we believe that it is very important that people do not discontinue their involvement in cognitively stimulating activities simply because it has not been proven to be an accurate indicator of problem-solving abilities. It is also possible that level of cognitive activity is what is driving changes in working-memory space. Future research should address this possibility.

The results show, as has been shown in previous findings, that with increased age there is a decrease in working-memory performance. This decline, however, was not well represented in performance on simple problem-solving tasks (i.e. Trail Making and Letter Rotation tasks). This decline was significantly related to performance on the complex task (i.e. Logical Reasoning task). The results of this study indicate that complex working-memory performance (i.e., executive function) is a good predictor of age-related decline in cognitive performance in elderly adults.

Figure 1. *Age and working-memory and mean number of correct words recalled on Word-Span Complex and Word-Span Simple*

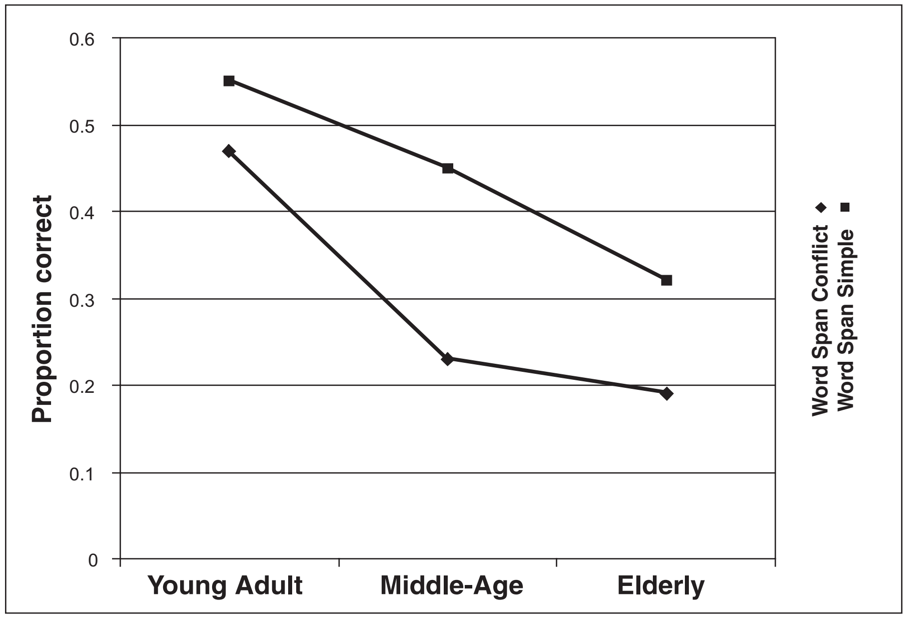


Figure 2. *Letter rotation task and the mean number of correct responses per age-group young adult, middle age, and elderly*

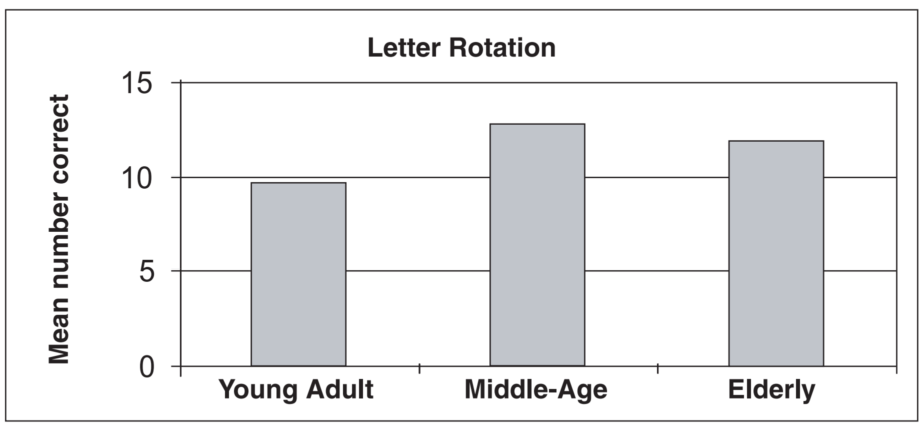
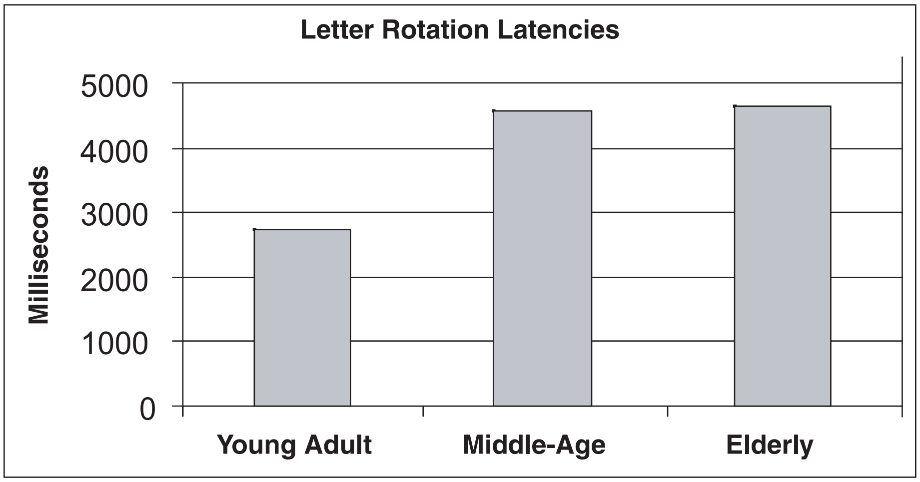


Figure 3. *Letter rotation task and latency of responses by milliseconds per age group young adult, middle age, and elderly*



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