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Attention test performance and normal aging: the effect on executive function

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ATTENTION TEST PERFORMANCE AND NORMAL AGING: THE EFFECT ON EXECUTIVE FUNCTION

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ABSTRACT

In this pilot study, twenty-nine participants completed the following three executive function tests: the *Behavioral Assessment of the Dysexecutive System*, the *Functional Assessment of Verbal Reasoning and Executive Strategies*, and *Auditory Process Training*. Participants, aged blank to blank, were divided into two age groups: young adults, which was comprised of 16 participants, and older adults, which was comprised of 13 participants. Performance means of the two groups were established and compared. There were no predictive qualities to the younger adults' scores, and there were only in two FAVRES subtests for the older adults: accuracy and reasoning. Further research is needed in this area.

CHAPTER 1

INTRODUCTION AND REVIEW OF THE LITERATURE

Introduction

The effects of normal aging in adults are not extremely well studied, especially in terms of cognitive skills. There are consistent findings in the literature that currently exists that proves older adults have more impaired cognitive and executive function, compared to younger adults. This paper aims to examine normal aging through the lens of possible predictive properties of attention and executive function tests. The purpose of this study was to discover if performance on attention tests could predict the performance on executive function tests. It also aimed to examine the effects of normal aging on healthy individuals in terms of their executive function test scores.

Review of Literature

First and foremost, it is essential to define and discuss executive function. There are several ways that researchers have described executive function. One definition refers to "'higher-level' cognitive functions involved in the control and regulation of 'lower-level' cognitive processes and goal-directed, future-oriented behavior" (Alvarez & Emory, 2006, p. 17). According to Gurd, Kischka, and Marshall (2010), "at the most basic level, executive functions are the abilities that enable a person to establish new behavior patterns and ways of thinking […] the term 'executive function' refers to a whole range of adaptive abilities such as creative and abstract thought, introspection, and all the processes that enable a person to analyze what they want, how they might get it, […] and then carry that plan out" (p. 349). Gurd and colleagues argue that executive function is necessary for almost every activity we do in our daily lives, such as making a schedule or working through a problem. It is especially important for complex social behaviors, such as understanding how we are viewed by others and what constitutes politeness.

These abilities to plan, coordinate, and carry out normal social interaction are "collectively referred to as 'executive functions' because it is believed that the region of the brain that supports them (the frontal lobes) operates in a 'supervisory' (Shallice, 1988) or 'executive' (Pribram, 1973) capacity over the rest of the brain" (p. 350). A related term is "dysexecutive symptoms," which describes impairments in executive function (Gurd et al., 2010, p. 350).

There is a range of dysexecutive symptoms and it is possible to have more than one manifest itself. The below graph is taken from Gurd et al. (2010)'s book and is a compilation of the top twenty most common dysexecutive symptoms. Both patients exhibiting dysexecutive symptoms and those that care for them (such as relatives or partners) report observed difficulties.

Table 18.1 Frequency of 20 of the most common symptoms of executive dysfunction (adapted from Burgess and Robertson, 2002)

Symptom	Percentage reporting problem	
	Patients	**Carers**
Poor abstract thinking	17	21
Impulsivity	22	22
Confabulation	5	5
Planning	16	48
Euphoria	14	28
Poor temporal sequencing	18	25
Lack of insight	17	39
Apathy	20	27
Disinhibition (social)	15	23
Variable motivation	13	15
Shallow affect	14	23
Aggression	12	25
Lack of concern	9	26
Perseveration	17	26
Restlessness	25	28
Can't inhibit responses	11	21
Know–do dissociation	13	21
Distractibility	32	42
Poor decision-making	26	38
Unconcern for social rules	13	38

This table shows that many of these symptoms are related to lack of appropriate behavior (for example: aggression, lack of concern, cannot inhibit responses, unconcern for social rules), but just as many are less socially based and involve higher-order thinking (for example: poor decision-making, impulsivity, poor temporal sequencing, lack of insight). Although these are all symptoms of damage to executive function skills, this study aims to test skills more along the lines of higher-order thinking, such as planning and problem solving.

Action Planning

One aspect of executive function is action planning. According to the National Health Service, action planning "helps you summarize how you will achieve objectives and by when" (n.p.). Action plans break down each objective into detailed, more manageable chunks and assists in creating a timetable to accomplish the goal (www.institute.nhs.uk). In a study done by Allain et al. (2004), action planning is studied by using the Zoo Map Test. The Zoo Map Test is one subtest of the Behavioral Assessment of the Dysexecutive Syndrome (BADS; Wilson et al., 1996) test and consists of two trials. Both ask the participant to consider a hypothetical trip to a zoo. The first trial is considered "high demand" as it asks the participant to plan in advance the order in which they will visit pre-determined exhibits. The second trial is considered "low demand" as it asks the participant to follow an explicit set of directions to guide them on a route through the zoo (Allain et al., 2004).

A group of both older and younger adults participated in Allain et al.'s study. The elderly adults had a mean age of 80.3 years and the younger adults had a mean age of 28.6 years. The results of this study show that older adults had significantly longer drawing time, more errors, and a higher sequencing score compared to younger adults. To earn sequencing points, the participant must visit the listed zoo exhibits in the correct order. This indicates that normally aging older adults have impairments in planning (Allain et al., 2004).

Multiple Cue Probability Learning

Chasseigne, Mullet, and Steward (2007) studied Multiple Cue Probability Learning, or MCPL, and found a strong correlation between old age and a decline in performance. MCPL is described as “an important cognitive ability for all age groups that, like other cognitive abilities, depends on information processing and speed and working memory capacity” (p. 235). The authors administered two different MCPL tasks with three different age groups: participants aged 20 – 30; age 65 – 75; and age 76 – 90. One task dealt with direct correlations between criterion (or variables) and the second, an indirect correlation.

The results of these tests show that there is a greater difference between the three age groups, with the lowest scores attributed to the 76 – 90 year age group, when there is an inverse relationship between criteria (Chasseigne et al., 2007). This finding is consistent with past research on the topic. Gick, Kraik, and Morris (1988) assert this in their citation that “age related differences were greater in a proof-reading task when phrases were presented in a negative grammatical form than when presented in an affirmative form” (p. 354). An example of a positive form sentence is “cats usually like to hunt mice” and an example of a negative form sentence is “bookcases are not usually found by the sea” (p. 354). Similarly, in a study of simple arithmetic function, Schaie and Willis (1993) have found that older adults had much more trouble with subtraction problems than with addition.

Many researchers have examined the effect of normal aging on various cognition and attention tasks. The general consensus on the topic is that executive function declines as a result of the normal aging process. In another study, researchers gave participants questions that force them to identify the relationship between criterion, and then asked questions about this relationship. A sample question asked during this type of test is “H and I do the opposite; G and H do the same; if G increases, will I decrease?” (Salthouse, 1992, p. 907). These questions require not only an understanding of the inverse relationship between criterion, but also strong skills in working memory. The participant must manipulate the problem while simultaneously retaining the original value.

Salthouse (1992)'s study gave participants four tasks to do with varying levels of difficulty. The tasks were reasoning (like the example with G, H and I seen above); analogies; cube assembly; and paper folding. The levels increased in difficulty from Level 1 to Level 3. Participants were shown pictures for each problem, and "each problem was accompanied by a space for the respondent to indicate whether the answer to the problem was *yes* or *no*." For task one, reasoning, the decisions "concerned the answer to the question." In task two, analogies, the decisions concerned "whether the transformations from the first to the second terms matched those from the third to the fourth terms." For task three, cube assembly, yes or no was answering "whether the two arrows would point at each other when the squares were folded into a cube." And finally, for task four, paper-folding, the question was asking "whether the displayed sequence of folds and hole location would result in the portrayed pattern of holes" (Salthouse, 1992, p. 906).

The results of this part of the study are clear: for each of the four tasks (Reasoning, Analogies, Cube Assembly and Paper Folding), younger adults had an overall higher performance than older adults. Older adults answered fewer questions correctly *and* had an overall lower percentage of correct answers than younger adults.

It is clear to see that in all cases, performance on cognitive function tasks decreases as the age of the participant increases. Salthouse concludes, "age differences in working memory are pronounced only when the stimulus information has to be manipulated or transformed in some fashion (from same or opposite to increase or decrease)" (Salthouse, 1992, p. 421).

However, some research shows that older adults do not receive worse scores than younger adults in all aspects of executive function. Carriere, Allan, Solman, and Smilek (2010) found that sustained attention, which includes task engagement and disengagement, improves quite a bit on early adulthood but then plateaus, even into old age. They also argue that the cause of older adults' slowness in response time can be credited to a "strategy to cope with task disengagement in a way that prevents overt critical errors" (Carriere et al., 2010, p. 573). This is an alternate explanation that could account for a fairly large difference between older and younger adults in response time.

Executive function and dysexecutive symptoms are pertinent to every adult because a decline in executive function or frontal lobe skills might be an indicator of neurological decline. The literature review in an article by Burda et al. (2014) reveals that a small cognitive change can be perceived 10 – 20 years prior to a diagnosis of Alzheimer's disease (Collie et al., 2001, Tondelli et al., 2012). This indicates that a small deficit in cognitive task performance might potentially lead to a bigger problem in older age (Burda et al., 2014).

Description of Tests

Some terms to define in this study are the acronyms of the four different tests used in the battery that was administered to all participants during this study. The MMSE stands for Mini-Mental State Exam (Folstein, Folstein, & Fanjiang, 2001). This is a screening that assesses memory function. It is the test that is most commonly used for patients with memory problems, and it is also used with patients who have degenerative neurological diseases such as Alzheimer's disease to see how far the disease has progressed (Alzheimer's Society).

There are 30 possible points on the MMSE and generally, a score of 27 and above is considered normal; however, there are several limitations to this exam. For example, education level plays a large part in the score of this test. For those who are extremely educated, the questions might be too easy and their scores will be higher, even if they have a form of dementia. Similarly, those with lower education levels might have scores that inaccurately reflect a neurological disorder (Alzheimer's Society).

The BADS test stands for Behavioral Assessment of the Dysexecutive Syndrome (Wilson et al., 1996). This assessment consists of seven tests: the Rule Shift Cards test, the Action Program test, the Key Search test, the Temporal Judgment test, the Zoo Map test, the Modified Six Elements test, and the Dysexecutive Questionnaire. All of these, with the exception of the Dysexecutive Questionnaire, are timed (Wilson et al., 1996).

It can be used to identify "disorders of planning, organization, problem solving and attention" (Pearson Education Limited). The BADS test "assess the skills and demands involved in everyday life" through a variety of subtests, including the Dysexecutive Questionnaire that looks more specifically at a number of different problems in four main areas – emotional/personality changes, motivational changes, behavioral changes, and cognitive changes – and the aforementioned Zoo Map Test (Pearson Education Limited).

The FAVRES test stands for Functional Assessment of Verbal Reasoning and Executive Strategies (MacDonald, 2005). According to test author Sheila MacDonald, M.CI.Sc. SLP, this test "assesses verbal reasoning, complex comprehension, discourse, and executive functioning during performance on a set of challenging functional tasks" (MacDonald). The FAVRES test yields both qualitative and quantitative data and asks participants to do a number of real-life tasks, including planning an event and scheduling a workday (Macdonald).

The APT test stands for Attention Process Training (Sohlberg & Mateer, 2005). APT is a "comprehensive, self-contained program designed to retrain attention and concentration deficits" (Northern Speech Services). Although it was originally developed for patients with brain injuries, it can be used with anyone who wishes to improve his or her attention processing skills. APT is a listening test made up of five different types of attention, which vary in difficulty: focused attention, which is "the ability to respond to a specific auditory, visual, or tactile stimulus;" sustained attention, which is "the ability to maintain a consistent response during a continuous and repetitive activity;" selective attention, which is "the ability to maintain a behavioral or cognitive set in the face of distracting or competing stimuli;" alternating attention, which is "the capacity for mental flexibility that allows an individual to shift his focus of attention and move between tasks having different cognitive requirements;" and divided attention, which is "the ability to respond simultaneously to multiple tasks or multiple task demands" (p. 4). Participants are asked to listen to auditory stimulus while completing different tasks simultaneously. These tasks are designed to help improve "sustained, selective, alternating and divided attention" and have been found to be rather effective at retraining attention processing (Northern Speech Services).

Purpose of Study and Research Questions

The purpose of this study is to find out if performance on attention tests can predict the performance on executive function tests, as well as to examine the effects of normal aging on healthy individuals in terms of their executive function test scores. This was accomplished by administering a battery of tests in a study designed by Dr. Angela

N. Burda, Ph.D. The The Mini-Mental State Examination (MMSE) (Folstein et al, 2001) was used as part of the participant screening process to determine whether or not individuals were able to participate in the study. The tests administered as part of the study are the Functional Assessment of Verbal Reasoning and Executive Strategies (FAVRES) (MacDonald, 2005), the Behavioral Assessment of the Dysexecutive Syndrome (BADS) (Wilson et al., 1996), and Attention Process Training (APT) (Sohlberg & Mateer, 2005).

Based on current literature of studies done on this topic, the hypothesis of this study is that performance on attention tests *can* predict the performance on executive function tests. Similarly, it is believed that healthy aging in older adults results in lower scores on executive function tests, especially in areas such as planning and memory.

The project aims to answer the following research questions:

1. Does performance on an attention test predict performance on executive function tests?
2. Similarly, is there any difference in performance between young adults and older adults on tests of attention and executive function?

CHAPTER II: METHODS

Participants

Twenty-nine total adults participated in this study. They were divided into two age groups: sixteen young adults (between 20 and 39 years; M_{age} = 24.35 years, *SD* = 5.69) and thirteen older adults (aged 60 years and older; M_{age} = 70.54 years, *SD* = 7.34). There were 22 female participants (13 young adults and 9 older adults) and 7 male participants (3 young adults and 4 older adults).

All participants were required to score at least a 28 out of a possible 30 points on the Mini-Mental State Exam (MMSE; Folstein, Folstein, & Fanjiang, 2001). The MMSE means and standard deviations for both young and older adults are: Young adults: *M* = 29.88 (*SD* = 0.33). Older adults: *M* = 28.77 (*SD* = 1.74).

Participants were also required to pass a pure-tone hearing screening at 20 dB at frequencies at 500, 1000, 2000 and 4000 Hertz. All participants needed to be native English speakers and have at least a high school-level education. Six young adults had a 2-year degree (with one currently pursuing a four-year degree); six young adults were working towards a four-year degree; one held a four-year degree and was working towards an advanced degree; and one had taken some college classes. Three of the older adults had a high school education; three had taken some college classes; two held a four-year degree; and five older adults held some type of advanced degree (MA or Ph.D). One older adult had an eighth-grade education.

Stimuli and Procedures

Approval from the University of Northern Iowa's Institutional Review Board was obtained (IRB #14-0241). Informed consent was obtained from all participants and the procedures were explained prior to each test. Once it was established that the participants were eligible for inclusion in the study, investigators administered the BADS (Wilson et al., 1996), FAVRES (MacDonald, 2005), and APT (Sohlberg & Mateer, 2005) tests in a counter-balanced order. Participants were evaluated individually. Each test was administered according to directions in its respective testing manual. Testing session length varied among participants, but typically lasted from 90 to 180 minutes.

Reliability

Inter- and intra-rater reliability was assessed for 20% of the participants' responses. Completed test protocols were randomly selected. Trained graduate students from the University of Northern Iowa Department of Communication Sciences and Disorders served as the inter-raters. FAVRES (MacDonald, 2005) inter-rater reliability was 88%, while intra-rater reliability was 96%. BADS (Wilson et al., 1996) inter-rater reliability was 89%, while intra-rater reliability was 95%.

CHAPTER III: RESULTS

Data Analysis

The tests administered during the study were all scored according to their respective test manuals. Means and standard deviations were calculated. Raw scores were converted to profile scores, standard scores, or percentile ranks as directed in the test manuals.

Young Adults

A multiple linear regression was calculated to predict participants' scores on the BADS (Wilson et al., 1996) and FAVRES (MacDonald, 2005) based on their APT (Sohlberg and Mateer, 2005) scores. For young adults, no significant regression equation was found on the BADS Total Profile Score (F (5, 10) = 1.07, $p > 0.43$) with an R^2 of 0.35, or on the BADS Standard Score (F (5, 10) = 1.04, $p > 0.45$) with an R^2 of 0.34.

No significant regression equation was found on the FAVRES Accuracy Total Standard Score (F (5, 10) =1.38, $p > 0.31$) with an R^2 of 0.41, or on the FAVRES Rationale Total Standard Score (F (5, 10) = 2.55, $p > 1.0$) with an R^2 of 0.56. No significant regression equation was found on the FAVRES Time Total Standard Score (F (5, 10) = 2.68, $p > 0.09$) with an R^2 of 0.57, or on the FAVRES Reasoning Standard Score (F (5, 10) = 0.76, $p > 0.60$) with an R^2 of 0.27.

Older Adults

For older adults, a significant regression equation was found for the BADS Total Profile Score (F (5, 6) = 8.89, $p \geq 0.01$) with an R^2 of 0.88, as well as for the BADS Standard Score (F (5, 6) = 8.28, $p \geq 0.01$) with an R^2 of 0.87.

No significant regression equation was found for the FAVRES Rationale Total Standard Score (F (5, 6) = 1.18, $p \geq 0.42$) with an R^2 of 0.50, or for the FAVRES Time Total Standard Score (F (5, 6) = 0.89, $p \geq 0.54$) with an R^2 of 0.43.

A significant regression equation was found for the FAVRES Accuracy Total Standard Score (F (5, 6) = 6.36, $p \geq 0.02$) with an $R^2$of 0.84, as well as for the FAVRES Reasoning Standard Score (F (5, 6) = 6.46, $p \geq 0.02$) with an R^2 of 0.84.

Results are shown in the tables below.

Table 1

Mean and Standard Deviations of BADS Profile Scores for Young and Older Adults

BADS Subtests	*Total Score Possible*	*Young Adults (N = 16)*		*Older Adults (N = 14)*	
		M	*SD*	*M*	*SD*
Rule-Shift Cards	4	3.56	.51	3.31	.75
Action Program	4	4.06	.25	3.54	.78
Key Search	4	3.38	.81	2.54	1.50
Temporal Judgment	4	1.25	.68	1.23	.83
Zoo Map	4	2.81	.75	2.38	1.12
Modified Six Elements	4	3.88	.34	3.69	.48

Total Profile Score	24	18.94	1.77	16.69	2.84

Table 2

Means and Standard Deviations of FAVRES Standard Scores for Young and Older Adults

FAVRES Tasks	*Total SS* Possible*	*Young Adults (N = 16)*		*Older Adults (N = 14)*	
*Accuracy SS**		*M*	*SD*	*M*	*SD*
Task 1	108	106.81	4.75	97.77	14.75
Task 2	106	97.56	12.92	76.92	38.69
Task 3	107	93.56	16.17	86.54	27.80
Task 4	106	83.81	25.71	68.08	38.17
Total Test	111	95.38	10.30	75.15	34.36
*Rationale SS**					
Task 1	106	101.38	12.64	97.46	22.17
Task 2	109	105.81	6.21	85.23	18.80
Task 3	103	97.94	14.10	93.00	22.61
Task 4	107	83.31	23.63	70.85	29.70
Total Test	111	98.07	11.00	75.46	26.30
*Time SS**					
Task 1	120	110.63	6.92	109.92	12.17

Task 2	122	106.81	9.45	98.38	16.32
Task 3	117	109.13	6.10	107.38	10.32
Task 4	120	111.19	11.03	101.92	27.45
Total Test	126	113.13	8.59	103.77	9.02
*Reasoning SS**					
Total Test	142	98.63	18.48	88.08	20.80

Note: SS* = Standard Score

Table 3

Residual scores of the APT for young adults and older adults.

APT Subtests	*Total Score Possible*	*Young Adults (N = 16)*		*Older Adults (N =14)*	
		M	*SD*	*M*	*SD*
Sustained Attention	30	29.31	2.50	29.54	1.13
Complex Sustained Attention	30	26.69	4.92	16.46	9.06
Selective Attention	30	27.19	2.48	18.08	8.30
Divided Attention	30	29.00	1.15	24.38	7.85
Alternating Attention	24	20.50	2.61	14.85	6.57

CHAPTER IV: DISCUSSION

Although it was hypothesized that participants' scores on the APT would predict their scores on the FAVRES and BADS, the data was inconsistent. As expected, young adults had higher mean scores than older adults on all tests and subtests, except for the APT Sustained Attention test, in which older adults scored higher mean scores than younger adults. This is supported in the literature in which Carriere et al. (2010) found that older adults had higher mean sustained attention scores than younger adults. In this article, Carriere et al. reported that sustained attention increases with age and that older adults are less prone to mind wandering and boredom. This would allow them to perform very well on tasks that require attention span or concentration, particularly if time is not a constraint. Older adults tend to take longer, but perform more accurately, on sustained attention tasks.

Younger adults scoring higher on all remaining tests and subtests is, again, not unexpected. Many studies mentioned previously support this outcome (Chasseigne et al., 2007; Gick et al.,1988; Salthouse, 1992). According to Salthouse, working memory decreases with age. Therefore, age-related differences increase when tasks require working memory and simultaneous storage and processing are involved. When more than one process is required, the age-related gap in scores is even more pronounced (Salthouse, 1992, p. 906).

In a study by Andres and Van der Linden (2000), researchers looked at the effect of age on executive function skills by testing both young and older adults on three tests designed to specifically evaluate planning, inhibition, and abstraction of logical rules. Researchers have found that older adults perform more poorly in nonroutine or novel situations. This makes sense with the FAVRES and BADS scores, as these assessments present realistic but likely new situations for the participants. The results were consistent with those found in the current study: older adult participants had significantly lower scores and overall poorer performance than younger adults in all three tasks.

As previously stated, a primary hypothesis in this research study was that performance on the APT would predict performance on the executive function tests (the BADS and the FAVRES). This would have useful clinical implications because if there were an established relationship between the APT and other executive function tests, it might be possible to give a shorter executive function screening, thus cutting down on intensity and assessment time. However, the hypothesis was not proven. In this pilot study, and thus far, performance on the APT does not have any predictive quality to indicate how a person will score on executive function tests.

This current project found younger adults' APT scores did not predict scores on FAVRES and BADS. Older adults' APT scores did predict the BADS total profile score and the FAVRES Accuracy and Reasoning Total scores based on the APT. Cappell et al. (2010) found an over-activation of brain activity in older adults during tasks when their memory was less taxed and under-activation of brain activity when their memory was more taxed. This may provide some insight into the variability of the APT's scores to predict the performance on the FAVRES measures in the present study. To illustrate, in order to obtain the Reasoning total score on the FAVRES, the participant is directly probed to explain why and how they came to their conclusion. This activity may be less taxing to their memory in comparison to the Rationale total score, where the participant must provide their rationale independently while simultaneously solving a problem. Although purely speculative, it may be possible then that attention as tested on the APT and the tasks that comprise the Reasoning total score are on a similar cognitive level and the Rationale total score tasks are not. This was a pilot study and the results show that a more in-depth investigation is warranted to determine how these results might have clinical significance.

Limitations and Future Research

Limitations to this study are largely related to the sampling size. Participant population was limited due to the inclusion criteria. The sampling size was small, possibly due in part to the time commitment that the assessment battery requires.

Future research is warranted in discovering if clear patterns emerge from a larger population of participants. Due to time constraints, the current assessment team was not able to incorporate lifestyle factors such as exercise, smoking, level of education, and volunteer hours into the data analysis. Using this qualitative data to analyze test scores might give information that is both pertinent to daily life and possibly predictive.

Conclusion

In conclusion, the results of the executive function assessment battery did not provide clear results. The hypothesis that younger adults out-perform older adults on executive function tests was proven to be true, with the exception of the sustained attention test on the APT. There were predictive properties to two FAVRES subtests in older adults: accuracy and reasoning. Further research with a larger sampling population is needed before clinical implications can be identified.

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