Performance of Young, Middle-Aged, and Older Adults on Tests of Executive Function

La performance des jeunes adultes, des adultes d'âge moyen et des aînés à des tests évaluant les fonctions exécutives

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Abstract

Information on differently aged adults' performance on tests of executive function administered by speech-language pathologists is lacking. This potentially limits clinicians' abilities to accurately evaluate and treat persons with cognitive impairments. The objective of this study was to determine potential differences among young, middle-aged, and older adults on 2 tests of executive function: the Behavioural Assessment of Dysexecutive Syndrome and the Functional Assessment of Verbal Reasoning and Executive Strategies. In total, 105 healthy adult participants completed both tests in this pilot study. Participants were equally divided into the following 3 age groups: Young, Middle-aged, and Older, with ages ranging from 20–88 years old. Older adults demonstrated statistically significantly lower scores compared to young and middle-aged adults on both tests. No significant performance differences were found between young and middle-aged adults. Further research is necessary to determine a definitive pattern of performance on these tests in adults across the lifespan.

Abrégé

L'information concernant la performance des adultes de différentes tranches d'âge à des tests évaluant les fonctions exécutives et administrés par les orthophonistes est manquante. Cette situation peut limiter la capacité des cliniciens à évaluer avec précision et à intervenir auprès de personnes ayant un trouble cognitif. L'objectif de cette étude était de déterminer les différences potentielles entre les performances des jeunes adultes, des adultes d'âge moyen et des aînés à deux tests évaluant les fonctions exécutives : le *Behavioural Assessment of Dysexecutive Syndrome* et le *Functional Assessment of Verbal Reasoning and Executive Strategies*. Au total, 105 adultes en santé ont complété les deux tests de cette étude pilote. Les participants ont été divisés en trois groupes égaux en fonction de leur âge : jeunes adultes, adultes d'âge moyen et aînés. L'âge des participants variait entre 20 et 88 ans. Les aînés ont obtenu des résultats significativement plus faibles aux deux tests comparativement aux jeunes adultes et aux adultes d'âge moyen. Aucune différence significative n'a été trouvée entre les performances des jeunes adultes et celle des adultes d'âge moyen. Des recherches supplémentaires sont nécessaires afin de déterminer les profils de performance des adultes à ces tests, et ce, aux différents âges de la vie.

Executive function is a term that encompasses numerous abilities involving higher level cognitive processes, including: initiating, forming goals, applying knowledge and judgment in problem-solving situations, sequencing, carrying out plans to completion, inhibiting inappropriate behaviours, and organizing pertinent information (Crawford & Channon, 2002; Pickens, Ostwald, Murphy-Pace, & Bergstrom, 2010). In essence, intact executive functioning facilitates dynamic adaptations to novel and varied situations. Impaired executive function can adversely impact the completion of daily activities, social communication, and social cognition. Persons with executive dysfunction can lack structure and coherence in discourse and leave out pertinent information during conversation (Douglas, 2010). Individuals can also have difficulty interpreting the behaviour of others and have reduced theory of mind (Sohlberg & Turkstra, 2011; Van Overwalle, Baetens, Mariën, & Vandekrerckhove, 2014). Such challenges can make interactions and conversations with others difficult (Douglas, 2010; Sohlberg & Turkstra, 2011).

Executive function performance in differently aged adults

Some researchers have reported executive function performance decreases with age and declines earlier than previously believed (Allain et al., 2005; Garden, Phillips, & MacPherson, 2001). Others have reported little executive function decline until old age, and that cognitive declines in those under 60 years of age are not typically clinically important (Singh-Manoux et al., 2012). However, individuals with Alzheimer's disease have shown slight cognitive changes 10–20 years prior to diagnosis (Rajan, Wilson, Weuve, Barnes, & Evans, 2015; Tondelli et al., 2012). If older adults develop executive dysfunction, their functional status may be affected (Pickens et al., 2010) as deficits in pragmatics, discourse, memory, attention, and strategic thinking typically occur (Geffner, 2007). The ability to make decisions autonomously may be called into question when individuals display characteristics of executive dysfunction (Pickens et al., 2010), possibly impacting the capacity to live independently or the ability to provide informed consent for a medical procedure or care.

Young and middle-aged adults have performed well on tasks measuring executive function, including those that mimic the real world and require open-ended planning (Allain et al., 2005; Garden et al., 2001). More recently, Burda et al. (2014) examined performance differences between healthy younger and middle-aged adults on two tests of executive function: the Behavioural Assessment of Dysexecutive Syndrome (BADS; Wilson, Alderman, Burgess, Emslie, & Evans, 1996) and the Functional Assessment of Verbal Reasoning and Executive Strategies (FAVRES; MacDonald, 2005). Middle-aged adults had higher scores than young adults on the Rule Shift task of the BADS. No other differences occurred on the remaining subtests or any subtests on the FAVRES. Older adults were not included in that study.

Tests to evaluate executive function performance

Tests of executive function require individuals to perform tasks that evaluate various skills (Purdy, 2015). Faria, Alves, and Charchat-Fichman (2015) recently reported some of the most frequently used neuropsychological tests to evaluate executive functions in older adults were the Trail Making Test (TMT) Form B; the Verbal Fluency Test (VFT) – F, A, S and the Animals category; the Clock Drawing Test (CDT); and the Stroop Test (Lezak, Howieson, Bigler, & Tranel, 2012). These tests have similarities to the BADS and FAVRES, the two tests used in this study. The TMT Form B and portions of the BADS require individuals to use working memory and repeatedly switch attention between different sequences. The VFT tasks require individuals to search their memory for specific information; semantic memory is also assessed. The FAVRES evaluates semantic memory during generation tasks that are comparable to verbal fluency tasks. The CDT is a visuospatial pen and paper task that requires planning within an allotted space, similar to the Key Search on the BADS. The Stroop Test and Test 1 of the BADS both evaluate inhibitory control. Although the FAVRES may not have as many tasks that directly match those of the tests reported in Faria et al. (2015), its subtests better reflect everyday activities (e.g., planning one's work day or writing a letter of complaint; MacDonald & Johnson, 2005). Similar to Allain et al. (2005), the majority of studies that utilized the tests of executive function discussed in Faria et al. (2015) found that older adults tended to have lower scores versus younger adults. Many studies also included more than one test since different tests evaluate different executive function abilities (Faria et al., 2015).

Of the tests used in this study, the BADS includes six tests (i.e., subtests) that determine the severity of dysexecutive impairments by evaluating high-level tasks such as "planning, organising, initiating, monitoring and adapting behaviour" (Chamberlain, 2003, p. 33). Individuals provide verbal and written responses and complete a hands-on activity. One test asks temporal judgment questions (e.g., How long do most dogs live for?). Another test provides persons with a zoo map and open-ended instructions to visit several exhibits following a set of rules. After completing this task, patients are given the same zoo map with more specific instructions on the sequence of exhibits to visit. The normative sample was composed of 216 healthy adults grouped into age brackets (i.e., 16–31, 32–47, 48–63, 64 and older) and 78 persons aged 19–78 years with various neurological disorders. Although participants in the norming group under the age of 64 performed significantly better than those aged 64 or older, no comparisons between young and middle-aged adults were included (Wilson et al., 1996).

The FAVRES assesses four high-level cognitive-communication skills that can occur in daily life: planning an event, scheduling a workday, making a decision, and building a case (MacDonald & Johnson, 2005, p. 896). Planning, organizing, sequencing, controlling inhibitions, and "prioritizing tasks with time constraints" are assessed (MacDonald & Johnson, 2005, p. 897). Tasks (i.e., subtests) generally contain restrictions (e.g., meetings must occur at specific times when scheduling a workday). Generation and prediction tasks are also completed. For example, after planning a children's event in Task 1, patients generate activities one could do with an adult and then predict two good and two bad things that could happen at the chosen event. As opposed to laboratory measures, ecologically valid tasks can give a better idea of daily functioning (Moriyama et al., 2002; Sussman, Rychtarik, Mueser, Glynn, & Pruesu, 1986), possibly helping to predict individuals' behaviours in daily life (Silver, 2000). The FAVRES was normed on 101 healthy adults ages 17–89 years and 52 adults with an acquired brain injury; no information was included on age-related performance (MacDonald, 2005).

Objective of the study

Speech-language pathologists (S-LPs) work with several populations who exhibit executive dysfunction (e.g., persons with brain injuries, multiple sclerosis, or dementia; Geffner, 2007; Royall, Palmer, Chiodo, & Polk, 2004). Clinical assessments are generally based on traditional tasks rather than functional tasks representative of real life, allowing for gross misestimates of performance (Crawford & Channon, 2002). The relatively sparse normative data on tests of executive function that S-LPs may use complicates the matter. The literature lacks specific information on potential performance differences between differently aged adults on the BADS and FAVRES (MacDonald, 2005; Wilson et al., 1996). While Burda et al. (2014) reported little performance difference on the BADS and FAVRES between young and middle-aged adults, data on the performance of older adults on these specific tests is lacking. Yet, medically based S-LPs need to know how well healthy adults across the lifespan perform on these tests in order to determine if their patients' performance is indicative of cognitive-communicative deficits or if their performance is age-appropriate. Such information could further aid treatment and prognosis by providing a clearer picture of how much cognitive change can be attributed to normal aging. The current study extended the study by Burda et al. (2014) by including older adults. The objective of this pilot study addressed the following research question: Are there statistically significant differences between young, middle-aged, and older adults on the BADS and the FAVRES?

Methods

Participants

Following approval of the protocol by the University of Northern Iowa's Institutional Review Board (Protocol #: 09-0270), participants were recruited for this cross-sectional quasi-experimental study from small, mid-sized, and large urban and rural communities in the Midwest by posting flyers in public areas (e.g., libraries). A power analysis for an effect size of .08 with an alpha of .05 indicated that a total sample size of 105 was needed. Participants were equally divided into the following age groups: Young (aged 20–39 years), Middle-Aged (aged 40–59 years), and Older (aged 60 and older). Participant inclusion criteria included: no history of any neurological damage or events, possessing at least a high school level of education, native English-speaking, and passing a pure tone hearing screening with tones presented at 20 dB HL at the frequencies of 500, 1000, 2000, and 4000 Hz for the young and middle-aged adults. Older participants were included if they had no greater than a mild hearing loss in their better ear, defined as no greater than 40 dB hearing loss at any of the previously documented frequencies (Burda, Casey, Foster, Pilkington, & Reppe, 2006). Participants were required to score a minimum of 28 or higher on the *Mini-Mental State Examination* (MMSE; Folstein, Folstein, & Fanjiang, 2001). Basic ethical considerations adopted by the University of Northern Iowa were taken to ensure the protection of participants in this study.

Stimuli and procedures

Tests were administered according to the test manual protocols. In order to control for possible testing order effects, every other participant (n = 53) was administered the BADS (Wilson et al., 1996) first; the remaining 52 participants were administered the FAVRES (MacDonald,

2005) first. This process was followed for each age group. Testing was completed in a single session, typically lasting 120 minutes. Breaks were provided as needed.

Data analysis

Participant responses were scored according to the procedures found in the test manuals. Raw scores on the BADS were converted to profile scores. Profile scores ranged from 0–4. Some subtests (e.g., the Modified Six Elements Test) had timed components, which factored into calculating the profile score. Performance of normal controls indicated planning time and time to complete a task were essential elements of executive function. Summing the profile scores for each of the six tests led to an overall profile score. If patients completed the entire test, they earned a Total Profile Score ranging from 0–24.

Participants earned the following raw scores for each FAVRES Task (i.e., subtest): Time, Accuracy, and Rationale. They also earned raw scores on Reasoning Subskills. Individuals earned the highest points possible for the most appropriate response. If participants provided a reasonable related response, they earned some, but not all, of the points. Raw scores were then converted to standard scores in the same areas (e.g., Time, Accuracy). Raw scores were also used to calculate the Total Score for the test. The mean standard score was 100 with a standard deviation of 15.

To address the study's objective, a series of two-factor Analyses of Variance (ANOVAs) with Bonferroni correction for multiple comparisons were used. Age was the independent variable and Score was the dependent variable. Since higher levels of education have led to higher scores on tasks measuring executive function (Ardila, Ostrosky-Solis, Rosselli, & Gomez, 2000), an additional series of two-factor ANOVAs were conducted to determine potential significant differences between participant groups' education levels and MMSE scores. Age was the independent variable; Education Level and Score were the dependent variables, respectively. Statistical analyses were performed using SPSS 22.0.

Reliability

Subtest raw scores were used to calculate inter- and intra-rater reliability on approximately 20% of a randomly chosen sample (i.e., 15 participants). For inter-rater reliability, the investigators' scores were correlated with scores of a trained speech-language pathology graduate student. For intra-rater reliability, the investigators scored the selected protocols twice. The second scoring took place two weeks after the initial scoring. Pearson r correlations were calculated. Inter-rater reliability for the FAVRES was $r = .92$; intra-rater reliability was $r = .94$. Inter-rater reliability for the BADS was $r = .90$; intra-rater reliability was $r = .94$.

Results

Participants

Participants were 105 adults (49 men, 56 women) with 35 participants in each age group. Participants had high mean MMSE scores. The majority had completed or were completing some type of post-high school education (See Table 1).

Table 1. Demographics

	Young Adults (n = 35)		Middle-Aged Adults (n = 35)		Older Adults (n = 35)	
Demographic Information	*M*	*SD*	*M*	*SD*	*M*	*SD*
Age in Years	23.71	5.25	50.31	5.27	69.83	8.21
MMSE Score*	29.00	1.41	29.46	.78	28.34	1.59
Years of College	6.66	2.84	3.06	2.22	5.03	3.16

Note. MMSE = Mini-Mental State Examination. *The highest possible score on the MMSE is 30.

Descriptive statistics

Overall mean scores on the BADS and the FAVRES were obtained (see Tables 2 and 3). In both tests, older adults generally had the lowest mean scores compared to the other two groups. There were some exceptions. On the BADS, middle-aged adults had the highest mean scores for the Action Program while young adults had the lowest mean scores. On the FAVRES, older adults had the lowest mean standard scores for Accuracy and Rationale measures. For measures of Time, young adults had the lowest mean standard scores for Task 1 (Planning an Event), while middle-aged adults had the lowest mean scores for Task 2 (Scheduling).

Inferential statistics

Several statistically significant differences occurred in both tests. On the BADS, the results showed an effect of group for the Rule Shift Card test, $F(2, 104) = 5.46, p \leq .006$; the Zoo Map test, $F(2, 104) = 4.65, p \leq .01$; the BADS Total Profile Score, $F(2, 104) = 6.34, p \leq .003$; and the BADS Standard Score, $F(2, 104) = 6.22, p \leq .003$.

On the FAVRES, an effect for group occurred for Accuracy scores on the following subtests: Task 1 (Planning an Event), $F(2, 104) = 4.41, p \leq .014$; Task 2 (Scheduling), $F(2, 104) = 8.91, p \leq .0001$; Task 4 (Building a Case), $F(2, 104) = 4.69, p \leq .01$; and Accuracy Total, $F(2, 104) = 7.64, p \leq .001$. Significant differences also occurred for Rationale

Table 2. Mean and Standard Deviations of BADS Profile Scores for Young, Middle-Aged, and Older Adults

BADS Subtests	Total Score Possible	Young Adults ($n = 35$)		Middle-Aged Adults ($n = 35$)		Older Adults ($n = 35$)	
		M	*SD*	*M*	*SD*	*M*	*SD*
Rule-Shift Cards	4	3.40	.65	3.80	.47	3.23	1.00
Action Program	4	3.46	1.22	3.89	.53	3.60	.81
Key Search	4	3.26	.95	2.86	1.17	2.77	1.00
Temporal Judgment	4	1.20	.63	1.31	.68	1.17	.57
Zoo Map	4	2.89	.99	2.51	1.09	2.09	1.20
Modified Six Elements	4	3.66	.76	3.74	.89	3.40	.81
Total Points Score	24	17.89	1.95	17.97	2.26	16.26	2.56
Standard Score	100	98.97	9.34	99.37	10.69	91.29	12.19

Note. BADS = Behavioural Assessment of Dysexecutive Syndrome.

Table 3. Means and Standard Deviations of FAVRES Standard Scores for Young, Middle-Aged, and Older Adults

		Young Adults (*n* = 35)		Middle-Aged Adults (*n* = 35)		Older Adults (*n* = 35)	
FAVRES Tasks Accuracy SS	Total SS Possible	*M*	*SD*	*M*	*SD*	*M*	*SD*
Task 1	108	100.94	16.02	96.89	18.43	87.91	20.58
Task 2	106	90.46	21.26	95.11	17.09	73.31	32.79
Task 3	107	93.57	22.42	71.89	30.39	90.23	29.64
Task 4	106	82.00	30.77	85.80	19.48	57.31	39.73
Total Test	111	88.40	21.22	97.23	21.34	65.91	35.36
Rationale SS							
Task 1	106	101.77	14.94	95.37	19.50	87.31	31.84
Task 2	109	99.31	14.94	89.74	28.09	88.74	18.50
Task 3	103	92.60	22.03	82.20	28.26	72.31	39.94
Task 4	107	80.11	31.89	88.37	17.98	67.17	33.55
Total Test	111	89.20	20.85	109.60	9.54	68.09	27.17
Time SS							
Task 1	132	105.91	16.09	93.83	25.28	105.97	12.20
Task 2	144	101.23	18.99	100.11	13.78	94.06	25.00
Task 3	130	104.51	9.82	105.77	10.60	94.49	21.43
Task 4	135	109.00	11.77	104.06	11.71	105.54	11.78
Total Test	126	107.89	14.82	86.03	31.96	101.03	17.91
Reasoning SS							
	142	91.09	13.42	86.94	32.10	82.71	13.96

Note. FAVRES = Functional Assessment of Verbal Reasoning and Executive Strategies; SS = Standard Score.

scores for the following: Task 1, $F(2, 104) = 3.39$, $p \leq .04$; Task 2, $F(2, 104) = 3.17$, $p \leq .05$; Task 3 (Making a Decision), $F(2, 104) = 4.41$, $p \leq .02$; and Rationale Total, $F(2, 104) = 10.04$, $p \leq .0001$. Finally, statistically significant differences occurred for Task 3 Time scores, $F(2, 104) = 3.56$, $p \leq .03$.

Post hoc testing. Tukey's post hoc testing on the BADS indicated middle-aged adults had statistically significantly higher scores on the Rule Shift Card test compared to older adults (Tukey's Value = 0.57, $p \leq .005$); young adults scored significantly higher on the Zoo Map task than did older adults (Tukey's Value = 0.80, $p \leq .008$). For the BADS Total Profile score, both young and middle-aged adults had significantly higher scores on the BADS Total Profile Score versus older adults (Tukey's Value = 1.62, $p \leq .009$ and Tukey's Value = 1.71, $p \leq .006$, respectively). Young and middle-aged adults also had statistically higher scores on the BADS Standard Score compared to the older adults (Tukey's Value = 7.68, $p \leq .01$ and Tukey's Value = 8.09, $p \leq .006$, respectively).

Results from Tukey's post hoc testing on the FAVRES revealed that for Accuracy scores, young adults had statistically significantly higher scores on Task 1 than older adults (Tukey's Value = 13.02, $p \leq .011$). Young and middle-aged adults scored higher on Task 2 than older adults (Tukey's Value = 18.71, $p \leq .006$ and Tukey's Value = 23.57, $p \leq .000$, respectively). Young adults also scored significantly higher on Task 4 compared to older adults (Tukey's Value = 24.68, $p \leq .008$). Young and middle-aged adults had significantly higher Accuracy Total scores than older adults (Tukey's Value = 22.48, $p \leq .002$ and Tukey's Value = 19.88, $p \leq .006$, respectively). For Rationale scores, Tukey's post hoc testing indicated that young adults had statistically significantly higher scores than older adults on Tasks 1, 2, and 3 (Tukey's Value = 14.46, $p \leq .033$; Tukey's Value = 10.57, $p \leq .038$; and Tukey's Value = 20.29, $p \leq .019$, respectively). Young and middle-aged adults had significantly higher Rationale Total scores compared to older adults (Tukey's Value = 21.11, $p \leq .000$ and Tukey's Value = 20.28, $p \leq .001$, respectively). Finally, young adults had higher Task 3 Time scores than older adults (Tukey's Value = 10.02, $p \leq .024$).

Education levels and MMSE scores. No statistically significant differences occurred among age groups for education levels or MMSE scores, $F(2, 104) = 1.33$, $p \geq .27$ and $F(2, 104) = 0.17$, $p \geq .92$ respectively.

Discussion

This pilot study is one of few that have investigated young, middle-aged, and older healthy adults' performance on the BADS and the FAVRES. The current study adds information that was previously unavailable in both tests. Overall, age appeared to affect performance on both the BADS and the FAVRES. As hypothesized, older adults had statistically significantly lower scores compared to young and middle-aged adults on several subtests. Not surprisingly, no significant differences occurred between young and middle-aged adults. Burda et al. (2014) found young and middle-aged adults had no significant performance differences on the FAVRES and all but one subtest on the BADS. Middle-aged adults had significantly higher scores on the Rule Card Shift Test versus young adults. Garden et al. (2001) also found no evidence of middle-aged adults having difficulty with changing tasks or following rules on a task similar to the six elements subtest of the BADS.

In the current study, older adults had the majority of the lowest mean scores on both the BADS and the FAVRES, likely one of the most ecologically valid executive function tests available to S-LPs. An interesting trend is that there were no significant performance differences on Task 3 (Making a Decision) among age groups, although younger adults took more time completing the task compared to the other groups. It is uncertain why this particular subtest did not garner similar outcomes (i.e., older adults having significantly lower scores vs. the other groups). Results of this study concur with the assertions by Allain et al. (2005) and Garden et al. (2001) that executive function performance decreases with age. The results also mirror findings by Allain et al. (2005) in that older adults had poorer performance on the BADS Zoo Map test compared to young adults. Such results may not be surprising because, compared to other cognitive tests, tests of executive function can be more sensitive to the effects of aging due to their complexity (Morris, Worsley, & Matthews, 2000; Murray, 2012). However, all older participants self-reported no history of neurological events (e.g., transient ischemic attack), and all were living on their own at the time of testing. Consequently, findings from this study must be interpreted cautiously. While this study adds to the literature, a broad statement denoting that lower scores on the BADS and FAVRES are typical of healthy older adults cannot be made until more research indicates this is indeed the case. In addition, care should be taken when interpreting scores from the BADS and FAVRES in clinical settings. Older adult patients may have performed more poorly on these tests pre-morbidly than younger or middle-aged patients. Thus, further inquiry may be necessary to ascertain if older patients have executive dysfunction and if so, to what extent. Interviews with patients and/or loved ones could aid in determining pre-morbid level of functioning and evidence of potential cognitive declines. Careful comparison of test scores with these responses and observations will ideally allow S-LPs to develop treatment plans that best meet their patients' needs.

Limitations and future research

Limitations exist with this investigation. While Singh-Manoux et al. (2012) reported that cognitive declines in individuals under 60 years of age are usually not clinically important, such assertions require longitudinal study. Thus, no predictions can be made based on results of the current study. However, participants could become familiar with tests in a longitudinal study, potentially biasing results (Singh-Manoux et al., 2012). Lack of randomization led to participants who were generally highly educated and skewed to the lower end of age ranges, particularly the older adults (M_{age} = 69.83). Few participants represented minority populations, limiting generalization of the current study's results (Scheffner Hammer, 2011). Adults from culturally and linguistically diverse backgrounds with neurologically based acquired communication disorders may perform differently on these tests (Ellis, 2009; Scheffner Hammer, 2011).

Future research options include testing a randomized participant pool that represents a variety of diverse populations and education levels. Forthcoming investigations could include aspects such as participants' physical activity, diet, and mental and social engagement. Previous studies have noted that low physical activity, high saturated fat intake, high dietary cholesterol, and a lack of mental and social engagement negatively affected cognitive abilities, including executive function, in adults across the lifespan (Fratiglioni, Paillard-Borg, & Winblad, 2004; Morris & Tangney, 2014; Singh-Manoux, Hillsdon, Brunner, & Marmot, 2005). Further research is needed to determine how differently aged individuals with acquired neurogenic communication disorders perform on the BADS and FAVRES compared to healthy age-matched controls. While more data must be obtained, S-LPs should be aware that healthy older adults could evidence lower scores on the BADS and FAVRES compared to younger and middle-aged adults.

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