Original Article

The Influence of Age and Gender on Executive Functions of the Brain in an Iranian Sample of Healthy Adults

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Received: 21.09.2016
Revised: 03.10.2016
Accepted: 03.10.2016

Keywords:
Executive functions, Age, Gender, Healthy individuals

Abstract

Objective: Executive functions refer to a group of higher-order cognitive processes responsible for self-regulated and targeted behaviors. This study aimed to investigate the effects of age and gender on executive functions focusing on three distinct areas of attentional control, planning and set-shifting among18-80 year-old healthy subjects. **Materials and Methods:** This cross-sectional study enrolled a total of 200 healthy adults (100 women and 100 men) 18-80 years of age living in Tehran. Sampling was done through a random stratified cluster procedure with regard to the inclusion and exclusion criteria. Each area of the executive functions was evaluated using Stroop test for attentional control, Tower of London (ToL) test for planning and problem-solving and Wisconsin test for set-shifting. The correlation between age and components of executive functions was evaluated through Pearson correlation test. Moreover, the differences between age groups were examined by ANOVA while the correlation between gender and components of the executive functions was examined by *t*-test. **Results:** Age was significantly correlated with all subscales of Stroop test except time-interference, with the total number of errors and the overall result from ToL and all subscales of Wisconsin ($P<0.001$), $R=0.49$). There were no gender effect on executive functions except for the total time ($t=-2.09$, $p=0.037$) and the number of errors ($t=-9.2$, $p=0.004$) in ToL test which was significantly higher in women than men. **Conclusion:** The executive functions including attentional control, planning and set-shifting was shown to be decreased by age. Problem-solving and planning were better in men than women.

https://doi.org/10.18869/nrip.jamsat.2.3.247

Introduction

Executive functions (EFs) refer to higher-order and self-regulated cognitive processes involved in the management and control of thoughts and actions. Such skill may include abilities of inhibitory control, planning, attentional flexibility, error recognition, correction and resistance to interference (1). In general, these higher-order cognitive processes are responsible for self-regulated and targeted behaviors (2). Various definitions of executive functions have emerged due to complexity of the concept which covers diverse integrated aspects such as planning and organizing, behavioral inhibition, problem-solving, self-control, etc. Therefore, a single concept seems insufficient to characterize executive functions (3). Executive functions are crucial for the analysis of external stimuli, goal-setting and strategies, preparation of action and approval of appropriate plans. They play an important role in cognitive-behavioral functions, emotional control and social interactions (4). The evolutionary course of executive functions is in line with the developmental period of the frontal area in the brain(5). Although the importance of frontal lobe is undeniable, integration of the entire brain is necessary for the optimal performance of executive functions. Hence, dysexecutive functions is not always in direct link with the frontal lobe damage, since its functional damage or loss at any level may lead to cognitive or behavioral impairments (6). There is clear evidence about the vulnerability of executive functions upon aging. Successive improvements and reduction of these functions are parallel with frontal lobe anatomic changes and its relationship with other areas of the brain (3).

The executive functions tend to develop during childhood, which is possibly simultaneous with the development of emerging neurodevelopmental changes in the frontal lobe. These periods of growth take place between birth and 2 years, 7 to 9 years and the latest progress occurs between 16 and 19 years of age (4,7). Nevertheless, many of the executive processes are not fully established until mid-adolescence or early adulthood(5).

Individuals at the age-range of 20-29 years, tend to have the highest level of executive skills where their working memory, strategic-planning, setting goals and problem-solving reach the highest levels. In this period of age, humans entail potentials for facing the most complex challenges. This level of ability diminishes gradually in later adulthood(8) almost after 64 years old(9). Commonly, the acceptable executive functions skills is a crucial prerequisite for independent living even in the presence of other cognitive impairments(10). It is essential to gain a better understanding of the significant influence of age on executive functions. Since it has been estimated that disorders arising from aging and executive functions are associated, it can be argued that they predict a decline in functional skills in elderly people(11). Furthermore, the executive tests can predict the independence and functionality of the elderly where functional assessments are embedded in regular checkups aiming to predict the potential problems in terms of functional independence(3).

Timely evaluation of the executive functions may help predicting mild dementia(12) or Alzheimer's(13). Despite the growing elderly population, it is crucial to identify the nature and extent of the decline in executive functions and consequently the independent and long-term living of such individuals(3).

On the other hand, gender differences have been challenging over recent years in terms of cognitive functions(14). By definition, gender refers to cultural characteristics of men and women rather than chromosomal differences, which is influenced by social and cultural variables particularly education in elementary schools(15). However, evidence in this respect is relatively lacking (14,16,17).

Evaluation of executive functions and the impact of factors such as age and gender can provide a deeper insight into the relationship between discrepancy in cognitive tests and current problems in everyday adaptive functions. A number of previous studies have examined one or more domains related to executive functions within a limited age range(18-22). Zarghi et al (17) examined the EFs in Iranian adults where some limitations were a relatively small sample size (n=84), age range (15-65 years old) and not evaluating the effects of age and gender on working memory and set-shifting. More over, continuing research need to consider the cultural and social experiences as potential factors contributing to executive functions(23).

The aim of this study was to assess three separate domains of executive functions including attentional control, planning and set-shifting among Iranian healthy individuals within a wide age range of 18-80 years, considering comparative gender differences.

Material and methods

This cross-sectional study enrolled a total of 200 healthy subjects 18-80 years of age (100 females and 100 males) in Tehran. Samples were selected through a random stratified cluster procedure. At first, Tehran was divided into five geographical regions of North, South, Central, East and West where the universities, cultural centers, recreation centers and health centers were hosting people of different age-ranges. Then, several centers were randomly specified so as to select the eligible subjects. Inclusion criteria were the age of18-80 years, residence in Tehran, Persian speaking , education more than 5 primary classes, normal or corrected-to-normal auditory and visual acuity, living with family, avoiding the use of psychotropic drugs ,no neurological or psychiatric diseases, Mini-

Mental State Examination score of higher than 21. Exclusion criteria were lack of cooperation and willingness.

Instruments

Research tools were the computerized version of the Stroop test, ToL test and Wisconsin Cart Sorting Test (WCST)(24). Evaluations were administered by two trained occupational therapists during January-March 2014.

- *Stroop test*

This test was first designed and introduced by Ridley Stroop in 1935 to evaluate the selective attention and cognitive flexibility(25). In this study, the computerized version of the Stroop test was supplied by Cognitive-Behavioral Science Research Institute(24).The first stage was naming the colors which appeared on the computer screen. Subject were then asked to tap on the desired keys on the keyboard with maximum speed matching the colors of circles appearing on the screen (red, blue, yellow, green). The aim of the first phase was training the techniques to participants. The scores achieved in the first stage did not have any effect on the final results. The second stage involved the main part of the Stroop test.

At this point, 48 matching colored words and 48 mismatching colored words along with their meanings appear on the screen. Matching words have the same color and meaning, e.g. the word blue appear on the screen with the same color blue. In mismatching cases, the color of the word and its meaning are not the same, e.g. the word yellow appears in green, blue or red. A total of 96 matching and mismatching words were shown randomly and consecutively on the screen, where the participants should pay attention to the color of the word regardless of its meaning and then click on the corresponding key. Thus, the subject had to be careful only about the color of words which may be different from its meaning. Every stimulus lasted 2 seconds on the screen with an interval of 800 milliseconds between each pair of stimuli.

The interference score was calculated by subtracting the number of correct mismatching responses from the number of correct matching responses. Scored obtained at the end of the Stroop test involved the number of errors, reaction time in matching and mismatching cases and the end result for each participant. Reliability of this test was reported through test-retest in the range of 0.80-0.91. The number of correct responses was within 0-96 while the duration of response varied according to the abilities of the participants(17, 24).

- *Tower of London*

The test was first introduced by Shallice in 1982(26). The ToL is a reliable tool to evaluate at least two aspects of executive functions, including planning and problem-solving(27). In this study, the computerized version of the Tower of London test was supplied by Sina Cognitive-Behavioral Science Research Institute(24). This computerized test was performed similar to other types of ToL tests, made up of a pilot phase where the subject tries to learn the correct way to do the test. On the left side of the monitor, an image is displayed as the subject should accordingly arrange the colored beads in the right-hand side column. During the test, the score for solving this problem is obtained by minimum moves of colored beads (green, blue, red) to the appropriate column. In each problem, there are only three opportunities for participants. If the problem is solved properly by the first attempt to achieve an exemplary shape at minimal movement of the beads, participants will receive 3 points. If it happens a second time 2 points is obtained while only 1 point is granted when it happens the third time. If the problem is not solves after three attempts, no score will be assigned to the examinee. In case a re-test is administered, its new or unusual dimensions needed to evaluate if the executive planning is violated. The final scores of the ToL included the test-time, latency, total time, result and errors. Reliability of this test was reported through test-retest to be 0.79. The overall result in ToL test was within 0-36 while the duration of response varied slightly according to the abilities of the participants(17,24).

- *Wisconsin Card Sorting Test (WCST)*

Wisconsin Card Sorting Test (64 cards) was developed by Grant and Berg (1948) to assess set shifting and cognitive flexibility constituting the two domains of executive functions. In this study, the computerized version of the Wisconsin test was supplied by Sina Cognitive-Behavioral Science Research Institute. In this test, 4 main cards appear on top of the screen entailing a red triangle, two green stars, three yellow plus signs and four blue circles serving as the main cards. The task of each subject was to place response cards under the main cards based on the rule governing the four cards. After each response, the participant receives a correct or incorrect answer. Response cards can match the main cards in terms of color (red, green, blue, yellow), shape (triangle, star, cross, circle) or count (1,2,3,4). The pattern or the rule governing the four main cards is replicated twice in order of color, shape and count. After the subject appropriately respond to a sufficient number of consecutive correct answers, the pattern changes while participants are not aware and have to figure it out. The two main indicators to represent the performance of subjects include the number of classes obtained and the number of preservation error. The reliability of this test was reported to be 0.85 in the Iranian population. The number of correct answers were within the range of 0-60 and maximum number of completed classes was 6(24).

Procedure: After obtaining ethics code number 105.5116/D/93 from Iran University of Medical Sciences, Informed consent was obtained from all participants prior to assessments. All participants were informed of the objectives and test procedures. Then the participants performed computerized tests of Stroop, ToL and WCST in a random order in a quiet room at health centers, cultural centers, workplace or in the Faculty of Rehabilitation Sciences, Iran University of Medical Sciences during 8 am to 14 pm. Tests were lasting about 60-90 min. The data were analyzed through SPSS 16. After evaluating the normal distribution with Kalmogorov-Smirnov test, the variables were examined through *t*-test and Pearson correlation test with p<0.05being statistically significant.

Results

This study recruited a total of 200 participants 18-80 years of age (100 males). Participants were classified into three groups of 18-37, 38-60 and 61-80 years old. The average age of the participants' population was 47.62±17.65 years. The average age of female participants was 46.52±6.16 years while the average age of male participants was 48.76±19.06 years. In terms of education, 22.3% of subjects were under high-school diploma, 39.3% had diploma and 38.3% had degrees higher than diploma. In terms of employment status, 36.8% were employed, 41.3% were unemployed and 21.9% were retired. Table 1 contains the average age and distribution of gender in groups of participants.

The results of evaluating executive functions in men and women using *t*--test showed that the average scores in subtests of Stroop and Wisconsin were not significantly different across genders.

The average number of errors in the ToL test and the average duration of the experiment in both genders showed a significant difference (P<0.05). Moreover, other variables in the ToL were significantly different between the two genders (Table 2).

The results of the correlation between age and subtests of measurement tool are summarized in Table 3 based on the Pearson correlation test. According to the results, age was correlated with all Stroop subtests except the interference time.

Furthermore, age was correlated with the total number of errors and the overall result of ToL showing no correlation with time and consequently the task speed. Table 3 displays the correlation between age and all Wisconsin subtests (P<0.001).

The difference of executive functions between the three groups and the differences between age groups was examined through ANOVA with Bonferroni correction the results of which are shown in Table 4. The results indicated a significant difference among age groups for the Stroop variables except the interference-time, number of errors and overall results from ToL and WCST variables.

Discussion

In this study, the influence of age and gender on the three domains of executive functions including attentional control, planning and set-shifting were investigated using the Stroop test, ToL and WCST.

The effect of age on executive functions

Attentional control and inhibition (Stroop): The results of our study showed that attentional control and inhibition were affected by age, indicating a significant difference between age groups in terms of Stroop variables other than the interference-time. This difference in terms of response time and response speed was observed among all three age groups 18-37 years, 38-60 years and 61-80 years as well as the number of correct answers and the interference score more than age groups 18-37 years, 61-80 years as well as 38-60 years and 61-80 years.

In fact, as age grows, there will be lower attentional control and processing speed. Elderly people have difficulty in controlling and suppressing irrelevant information. Hasher and Zacks explained a wide range of age-related cognitive dysfunctions by decreased inhibitory control system. Thus, inhibition and attentional control disorders may result in many age-related cognitive changes(28). Our finding were in line with earlier studies (17,20,22). Zarghi et al. declared that age is correlated with incongruent (the number of errors and non-response) stimuli of Stroop test.

Table 1. Distribution of genders in each age-groups (n=200)

Age groups	Distribution of gender	mean age± Standard deviation
18-37 years	38 Male	28.27± 5.89
	36 Female	
38-60 years	31 Male	51.94±7.6
	45 Female	
61-80 years	31 Male	69.27±6.9
	19 Female	

Table 2. The comparison og executive functions between women (n=100) and men (n=100) using the independent *t*-test

Tests	Subtest	Gender	Mean	Standard deviation	t	Significance level
Stroop	Number of correct responses consistent	Male	43.89	8.51	-1.028	0.305
		Female	45.05	7.59		
	Consistent response time	Male	1144.18	249.96	0.619	0.536
		Female	1122.96	235.68		
	Number of correct responses inconsistent	Male	39.84	12.59	-1.641	0.102
		Female	42.53	10.60		
	Inconsistent response time	Male	1186.10	285.89	0.493	0.622
		Female	1167.06	249.14		
	Interference number	Male	3.95	0.67	1.080	0.281
		Female	2.95	0.61		
	Interference time	Male	66.74	174.60	0.985	0.326
		Female	43.36	161.71		
Tower of London	Total time	Male	367.86	185/06	-2.099	0.037
		Female	429.41	228.27		
	Time delay	Male	-627.03	-8644.29	-0.997	0.320
		Female	230.15	117.25		
	Number of error	Male	9.28	7.66	-2.915	0.004
		Female	12.52	8.10		
	Total result	Male	31.57	4.21	1.925	0.056
		Female	30.53	3.37		
Wisconsin	Number of categories	Male	4.05	1.82	1.275	0.204
		Female	3.71	1.92		
	Preservation error	Male	5.54	4.88	-1.275	0.204
		Female	6.47	5.49		
	Total time	Male	302.67	112.92	-1.423	0.156
		Female	326.95	128.37		

Table 3: The relationship between age and executive functions in healthy adults subjects (n=200)

Tests	Subtest	Age	Significance level
Stroop	Number of correct responses consistent	-0.412**	<0.001
	Consistent response time	0.710**	<0.001
	Number of correct responses inconsistent	-0.548**	<0.001
	Inconsistent response time	0.588**	<0.001
	Interference number	0.455**	<0.001
	Interference time	0.009	0.902
Tower of London	Total time	-0.137	0.053
	Time delay	-0.108	0.127
	Number of error	0.190**	<0.001
	Total result	-0.262**	<0.001
Wisconsin	Number of categories	-0.491**	<0.001
	Preservation error	0.498**	<0.001
	Total time	0.505**	<0.001

In Van der Elst(22) and Peña-Casanova(20) studies age related to speed and score of interference.

- *Planning and problem-solving (ToL)*

In our study, age was positively correlated with the number of errors and the overall result of ToL test, but it had no significant relationship with speed factors. Hence, it can be stated that among common errors made by the elderly during the ToL test, the violations of law involved moving toward a solution. In general, the test performance and ultimately the overall time of the test were influenced by the skills and number of moves in the ToL test (17).

According to our observation, young people tend to have more accuracy and thus greater executive planning compared to the elderly. There was a significant difference between age groups in terms of planning and problem-solving only in the number of errors and the overall result from ToL, whereas there was no difference between age groups in terms of planning time. However, the difference was evident in comparison between the age groups 18-37 and 61-80 years. To our knowledge, there seems to be no study investigating the executive functions including problem-solving and planning in various age groups. Meanwhile, more accurate conclusions can be drawn based on greater number of samples. Our observation has been consistent with some earlier studies (18,19,29) .

It has been suggested that normal aging is associated with reduced ability to regulate behavior on the basis of planning. Some studies recorded the age-related decline in planning given the complexity of tasks including TOL test (30, 31).

Table 4: The difference in executive functions across age-groups of 18-37, 38-60 and 61-80 year-old subjects (n=200)

Variables		age groups	Mean	Standard deviation	Mean Square	F	Sig	Pairwise comparison		
Stroop	Number of correct responses consistent	Group1: 18-37 years	47.01	5.11	1281.3	24.27	<0.001	1	2	1.0
		Group2: 38-60 years	45.09	4.06				1	3	<0.001
		Group3: 61-80 years	38.39	12.08				2	3	<0.001
	Consistent response time	Group1: 18-37 years	951.13	124.7	2645344.3	80.92	<0.001	1	2	<0.001
		Group2: 38-60 years	1153.9	192.7				1	3	<0.001
		Group3: 61-80 years	1367.7	225.9				2	3	<0.001
	Number of correct responses inconsistent	Group1: 18-37 years	46.67	1.93	3930.2	39.99	<0.001	1	2	0.052
		Group2: 38-60 years	42.78	9.01				1	3	<0.001
		Group3: 61-80 years	30.86	16.17				2	3	<0.001
	Inconsistent response time	Group1: 18-37 years	996.2	132.6	2134871.3	39.78	<0.001	1	2	<0.001
		Group2: 38-60 years	1232.1	219.6				1	3	<0/001
		Group3: 61-80 years	1355.2	338.2				2	3	0/011
	Interference number	Group1: 18-37 years	0.79	1.57	685.5	19.18	<0.001	1	2	0.033
		Group2: 38-60 years	3.30	7.26				1	3	<0.001
		Group3: 61-80 years	7.52	7.66				2	3	<0.001
	Interference time	Group1: 18-37 years	45.10	38.57	34163.9	1.21	0.301	1	2	0.693
		Group2: 38-60 years	78.09	68.82				1	3	1.0
		Group3: 61-80 years	34.92	320.2				2	3	0.472
Tower of London	Total time	Group1: 18-37 years	438.7	203.2	110974.0	2.56	0.080	1	2	0.074
		Group2: 38-60 years	361.8	166.2				1	3	0.776
		Group3: 61-80 years	395.8	263.8				2	3	1.0
	Time delay	Group1: 18-37 years	227.5	148.5	52297450.4	1.41	0.246	1	2	1.0
		Group2: 38-60 years	221.1	96.57				1	3	0.406
		Group3: 61-80 years	-1433.4	12107.0				2	3	0.404
	Number of error	Group1: 18-37 years	8.91	8.35	257.6	4.11	0.018	1	2	0.129
		Group2: 38-60 years	11.55	7.09				1	3	0.021
		Group3: 61-80 years	12.84	8.40				2	3	1.0
	Total result	Group1: 18-37 years	32.01	3.61	79.18	5.62	0.004	1	2	0.299
		Group2: 38-60 years	31.0	3.02				1	3	0.003
		Group3: 61-80 years	29.72	4.79				2	3	0.186
Wisconsin	Number of categories	Group1: 18-37 years	4.82	1.39	73.22	25.95	<0.001	1	2	<0.001
		Group2: 38-60 years	3.80	1.92				1	3	<0.001
		Group3: 61-80 years	2.62	1.66				2	3	<0.001
	Preservation error	Group1: 18-37 years	3.28	2.97	546.6	24.98	<0.001	1	2	<0.001
		Group2: 38-60 years	6.51	5.38				1	3	<0.001
		Group3: 61-80 years	9.21	5.50				2	3	0.005
	Total time	Group1: 18-37 years	250.7	97.8	339595.6	29.73	<0.001	1	2	<0.001
		Group2: 38-60 years	319.8	109.3				1	3	<0.001
		Group3: 61-80 years	400.4	115.3				2	3	<0.001

Our study was inconsistent with that of Zarghi et al. who argued that only the test-time and latency in the ToL were significantly correlated with age. Such disparity may be associated with the limited sample size and limited age range of 15-65 years and limitation in the record of planning accuracy variable.

- *Working memory and set shifting (WCST)*

The findings of this study demonstrated that aging affects cognitive flexibility and set-shifting. Elderly people, such as patients with posterior lateral frontal lobe lesions, progressively exhibit more preservation errors in WCST and other tasks related to set-shifting. As age grows, there is a tendency to preservation in an older task when responding to a recent change. In fact, cognitive flexibility decreases with age, which in turn aggravates the ability of individuals in the face of changes in everyday life(32).There were significant differences among three groups of this study in terms of WCST variables, suggesting that, working memory and cognitive flexibility may vary between the three age groups. However, the results of this study were consistent with some erlier reports (33,34) in terms of the relationship between age and set-shifting in Wisconsin test(33).

The study suggested that preservation errors increase with age and number of completed classes (34) indicating that the elderly are more inclined toward trial and error for performing WCST. The present study is inconsistent with Shan et al(21) who found that WCST had a lower sensitivity to the effects of age and aging process and emphasized on the cultural and educational factors.

The effect of gender on executive functions

The result of the present study revealed the gender effect of executive function only on overall test duration and the number of errors in the ToL test, where male subjects had a higher planning speed and more accuracy responses than female subjects. Nevertheless, there was no significant difference between men and women in terms of the final results.

- *Attentional control and inhibition (Stroop)*

The results of this study suggested that there was no difference between women and men in terms of attentional and inhibitory control. These results were consistent with those obtained by Malek et al. who found that gender has no impact on attentional and inhibitory control(16). Similarly, McLeod argued that gender was a variable with minimum correlation with Stroop test and therefore attentional control in all age groups(35). The result of present study is inconsistent with(17, 19) studies. The study suggested a high correlation between gender and (number of incongurant error) and (number of non-response incongurant stimuli). This discrepancy may be due to sampling method and limited sample size (n=84) which Moering et al(36) emphasized on the number of sample size which interfere on the validation of results in gender studies for investigation of Stroop-effect.

- *Planning and problem-solving (Tower of London)*

The results of the current study showed the better performance of men than women in some part of TOL which is consistent with the study by (18). This study is inconsistent with(20) suggested that gender has no impact on Tower of London and planning ability. This disparity may be related to culture differences.

- *Working memory and set shifting (WCST)*

The results of this study were consistent with (19,21) studies which declared no differences between men and women ability in set shifting through Wisconsin Card Sorting Test.

Conclusions

As previously mentioned, the frontal brain structure plays an important role in executive functions. Since aging leads to damage to that structure, there will be evident decline in executive functions and consequently impairment in everyday activities of patients. The results of this study showed that the aging process is associated with lower attentional control and processing speed, working memory, precision in planning and problem-solving, cognitive flexibility and willingness to preservation when a new change occurs. Moreover, impaired executive functions curtail the efficiency in daily activities. Due to the growing population of elderly people in Iran, a good understanding of dysexecutive and subsequent disorders in everyday functions of the elderly people can facilitate rehabilitation programs in line with systematic prevention and treatment.

According to the evaluation of executive functions between men and women, no gender difference was documented. The only difference was in problem-solving and planning in which males were arguably performing faster and more accurate. Since gender is influenced by education and cultural factors, the education system, particularly primary schools, should be reformed so as to eliminate such differences between males and females, thus enhancing executive functions.

It should be noted that the present report did not discuss other demographic variables such as socioeconomic status, ethnicity, geographical location and the level of education in healthy subjects. It is recommended that future studies employ non-computerized tests to evaluate executive functions in elderly, focusing on demographic variables associated with executive functions in different age-groups and a greater number of subjects.

Acknowledgments

This paper was the outcome of the registered project entitled 'A Study on Psychometric Properties of Behavioral Assessment of Dysexecutive Syndrome in the Iranian Adult Community', under the code 24863-32-02-93 at Iran University of Medical Sciences and a Master's thesis in occupational therapy entitled 'A Study on Psychometric Properties of Persian Behavioral Assessment of the Dysexecutive Syndrome' by the first author, advised by the corresponding author. Authors would like to acknowledge all who graciously contributed to this project.

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ISSN: 2423-5903
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