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Construction and Investigation of Psychometric Characteristics of Updating Component Tasks of Executive Functions

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ABSTRACT

Background: This study aimed to investigate the validity and reliability of the updating component tasks of executive functions in normal individuals and to compare their performance with patients with clinical disorders, including schizophrenia (SC), traumatic brain injury (TBI), Alzheimer's disease (AD), and major depressive disorder (MDD).

Methods: In this causal-comparative study, all normal individuals aged 16-70 years and patients with SC, TBI, AD, and MDD in Kerman city, were included. The study population included 406 normal individuals who were selected through convenience sampling and 74 patients (24 SC, 11 TBI, 15 AD, and 24 MDD) who were selected by purposive sampling. Participants completed updating tasks, including letter memory, keep track, spatial 2-back, and spatial 3-back. Data were analyzed using descriptive statistics, Cronbach's alpha, test-retest reliability, and multivariate analysis of variance.

Results: The results showed that the validity and reliability of the updating tasks are acceptable, and there is a significant difference between the scores of normal individuals and those of patients with SC, TBI, AD, and MDD.

Conclusion: According to the results, it can be concluded that this set of tasks can well assess the updating-specific ability and distinguish between the performance of normal individuals and patients with clinical disorders.

Keywords: Validity, Reliability, Executive Function, Updating tasks, Clinical Disorders

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Introduction

Executive functions (EF) serve as an umbrella term encompassing the set of higher-order cognitive processes that are necessary to investigate and achieve a goal. These functions enable a person to understand complex or abstract concepts and seek to solve and manage problems that have not been encountered before (1). In close conjunction with metacognition (2), executive functions play an essential role in our understanding of how people consciously regulate their thoughts and behaviors. Executive functions (EF) are associated with the maturation and activation of the prefrontal cortex and other related brain areas (3). Many different models of EF have been proposed, encompassing a variety of processes such as response inhibition, working memory updating, attention shifting, goal monitoring, action planning, and so on. Over the last 15 years, perhaps the most prominent model of EF is the one that was put forward by Akira Miyake et al. (4). According to this model, there are three components in executive functions including response inhibition (Inhibiting), working memory updating (Updating), and task shifting (Shifting) (4). These three fundamental components provide the basis for higher-level executive functions such as reasoning, problem-solving, planning, and decision-making (5).

The inhibition component refers to the individual's capacity to replace responses that must be presented in a particular situation. The component of shifting means a person's cognitive flexibility to transfer between different tasks or states of mind. The updating component is also considered as continuous monitoring and adding or removing the content of the individual's working memory.

Updating working memory is a screening and coding system that checks information based on its importance, continuously deletes additional information, replaces relevant information, and demonstrates our cognitive capacity for simultaneous processing of multiple tasks (4). This process enables the active manipulation of the contents in working memory and for going beyond simple storage of information. It also precludes working memory from being overloaded in considering its limited capacity (6). Friedman et al. (7) found that only the updating function could significantly predict intelligence.

Stroop and Wisconsin tests have long been used manually to assess executive functions. In recent years, the software of these tests (8,9) has also been made available to experts. Also, the Paper and Pencil Cognitive Assessment Package (PCAP) has been produced to develop cognitive assessment tasks for Persian-speaking subjects (10). Although mentioned tasks can examine executive functions, these tests cannot examine each component of executive functions separately. Accordingly, the present research aimed to construct the set of updating tasks and to examine their validity and reliability. This set of tasks is conducted by computer programs, and stimuli are presented in a short time, so the participant should respond as quickly and accurately as possible. Additionally, the language of the instrument of the mentioned tasks was in English language, so an adaptation for the Farsi-language participants was necessary. This set of tasks includes 4 subtests of keep track, letter memory, and spatial 2- and 3-back that specifically measure the updating ability.

Several clinical disorders such as schizophrenia (SC), traumatic brain injury (TBI), Alzheimer’s disease (AD), and major depressive disorder (MDD) can affect people's cognitive abilities, especially their executive functioning ability. Executive dysfunction reduces a person's ability to return to work or school and to resume satisfactory social activities. Understanding the consequences of executive dysfunctions is critical to make the right decisions about diagnosis and in finding an appropriate rehabilitation program to help individuals achieve independent living (11).

Research on major depressive disorder (MDD) has highlighted executive dysfunction and cognitive impairment in these patients (12, 13). The most frequent cognitive deficits in MDD include poor processing speed and poor verbal memory (14). Cognitive deficits in depressed patients are also associated with the severity of clinical symptoms. Some theoretical models have suggested that cognitive impairment could be a risk factor for future depression (13). Using neuropsychological tests in patients with MDD showed poor performance of these patients. Studies of the prefrontal cortex showed that depression is caused by hypofunction of the left frontal area that plays an important role in the EF ability (15).

Alzheimer's disease (AD) is a progressive neurodegenerative characterized by a slow and gradual cognitive decline and disrupts the activities of daily living. This disorder is known by deficits in episodic memory, working memory, and executive functions (16). When comparing healthy older adults with seniors with mild or moderate AD, neurological evidence suggests a decrease in task-related signal activity in the left frontal lobe (17). It can be said that decreased cognitive repository size in the AD patients' frontal lobe leads to an early disruption in this region, the appearance of signs of executive dysfunction, and behavioral changes (18).

Schizophrenia (SC) is another mental disorder whose symptoms include a wide range of cognitive, behavioral, and emotional problems (19). Cognitive and executive impairments are recognized as the main impairments in SC, and they are strongly associated with functional impairment. Patients with SC show a wide range of cognitive and executive impairments, including attention, response inhibition, cognitive flexibility, and processing speed (20). The frontal cortex disorders are related to symptom severity and weak executive function, such as cognitive inflexibility and impaired working memory in SC (21).

Traumatic brain injury (TBI) is associated with a change in normal brain function or any other evidence of brain pathology caused by external mechanical forces trauma. The main results of brain injury include mortality, functional disability, health-related quality of life, and cognitive, psychological, and social problems (22). The scope and severity of cognitive impairment after brain injury can vary greatly depending on the severity and site of the lesion. Anatomically, the risk of prefrontal cortex damage in TBI is very high and can be associated with executive dysfunction (23-24).

Due to the importance of the updating function in daily living and as disruption of this component is evident in many clinical disorders, the significance of accurate examination of the updating-specific ability to diagnose, treat and rehabilitate disorders is doubled. Adapting tests from their original language to other languages is a sign of the development of neuropsychology (25). Ensuring the validity and reliability of executive function measurement tasks is very important. Although various tasks have been proposed to measure executive functions, due to their excessive breadth and ambiguity in measuring the components of executive functions, the use of more specialized and accurate tests to measure each component separately is of great importance (26,27). Thus, the present study aimed to construct the set of updating tasks, to investigate their validity and reliability, and to compare the performance of normal individuals and individuals with clinical disorders, including SC, MDD, AD, and TBI in these sets of tasks.

Materials and Methods

This is an applied research in which researchers seek to prepare and adjust a set of tasks with acceptable reliability and validity to measure the updating-specific ability and to compare the performance of normal individuals and patients with clinical disorders in these tasks. The research method is causal-comparative. The set of mentioned tasks is a comprehensive assessment of the updating ability.

The study population was all healthy individuals and patients with clinical disorders aged 16-70 years in Kerman city. The sample size of the normal population consisted of 406 healthy participants who were selected by the convenience sampling method. The sample size of patients consisted of 74 people with clinical disorders, including 24 SC, 11 TBI, 15 AD, and 24 MDD, who were selected by purposive sampling. It should be noted that all participants in this research gave verbal consent to conduct tasks, and they were assured that their personal information would be kept confidential.

Data collection instruments

The set of updating tasks consists of four parts including keep track, letter memory, spatial 2-back, and spatial 3-back. This collection of tasks is adapted from the model of Miyake et al., which has been used for more than 20 years. In what follows, there are some explanations about each of updating tasks (keep track, letter memory, spatial 2-back, and spatial 3-back) and Wisconsin Card Sorting Task (WCST), which has been used to assess criterion validity.

Updating 1: Keep Track

This task (adapted from 28) required participants to track a series of exemplars belonging to 6 different categories. Each trial began with a list of 2 to 5 target categories (animals, colors, countries, distances, metals, and relatives), which remained at the bottom of the screen while the stream of 15 to 25 exemplar words from the different categories appeared in the center of the screen for 2,000 ms each. At the end of each trial, "???" appeared in the center of the screen, indicating that the participant must recall the last word of each target category. Participants were not allowed to say words or categories loudly during the trials. The dependent measure was the proportion of correct words across all trials. There was a total of 16 test trials, 4 of each difficulty level. Test trials were preceded by two practice trials with two categories for each.

Updating 2: Letter Memory

In each trial of this task (adapted from 6) streams of mute letters appeared as 3,000 ms per letter, participants had to rehearse aloud the last 4 letters seen (including the current letter), in the correct order. Letters were accumulated until the fourth letter was reached, and after displaying the fifth letter, the first letter was dropped. The final four letters had to be reported in the correct order (i.e., "L", "L-S", "L-S-K", "L-S-K-D", "S-K-D-T", "K-D-T-H", etc.). After appearing 9, 11, or 13 letters (the length of the trail is unpredictable), "???" appeared on the screen, indicating that participants must repeat the final four letters, but this final recall was not scored because it was already captured in the set score for the last letter. If a letter could not be recalled, participants were instructed to substitute “blank” where the missing letter should have been presented. This task consists of 3 practice trials and 12 test trials. To begin with this task, participants completed 3 practice trials with 7 letters and 9 letters. The dependent measure was the proportion of sets correctly rehearsed, with one point for each correctly reported set.

Updating 3: Spatial n-back

In this task (adapted from 29), boxes flashed in 12 locations on the computer screen, and participants reported for each flash via button press whether it was the same as the one that had flashed n-trials, and to do so, they must press the "yes" or "no" keys. In the 2-back condition, participants judged whether the current stimulus appeared in the same location as the stimulus that appeared two trials earlier (e.g., on the appearance of the 8th stimulus in a series, participants would be asked to compare its location to the location of the 6th stimulus). In the 3-back condition, the comparison was between the current stimulus location and the stimulus location that appeared in the 3 trials earlier. To minimize interference between states, two-back and three-back tasks were presented in separate tasks (one near the start of the session and the other near the end).

The locations consisted of 12 open squares (5.8 inches) in a fixed pseudorandom location on the monitor, so that if the screen were divided into quadrants, 3 squares were positioned within each quadrant. These 12 boxes appeared during the task, and the quadrant structure was not obvious. In each of 6 blocks, 24 squares flashed. When a square flashed, it turned black and bold for 500 ms, and then, returned to its first state for 1500 ms until the next square flashed. In each block, there were 6 "yes" answers. Of the remaining 18 “no” responses, a few flashes were lures, those were included to increase task difficulty. In the 2-back condition, the lure was a flash that matched the square from 3 flashes back (5 in total). In the 3-back condition, the lure was a flash that matched the square from 4 flashes back (4 in total). Each square was displayed equally as a target, non-target, or lure, and sequences of flashes were randomized to avoid circular patterns or clustering in one spatial location. A practice block of 20 flashes was administered before the 6 test blocks for each 2-back and 3-back condition. A second and sometimes a third practice block were given for participants who did not demonstrate a clear understanding of the task. The dependent measure was the proportion of correct responses, averaged across the 2-back and 3-back tasks. Omissions were counted as errors.

Wisconsin Card Sorting Test (WCST)

In this test (adapted from 9), four target cards (including a red triangle, two green stars, three yellow crosses, and four blue circles) on the top left corner of the monitor were displayed constantly until the end of the test. The 60 cards were shown in a completely random order one by one at the bottom of the screen near the right corner. Participants must decide which target card is the best answer for the appeared card based on the current pattern, and they have to press the related button of that card. Immediately after the response, the correct or incorrect feedback appeared on the screen. The interval between the subject's response and providing feedback was 100 ms, the duration of displaying the Right or Wrong word was 200 ms, and the time delay between the end of the feedback and the next card was 700 ms. Participants were instructed to sort cards, according to one of the three patterns - color (red, green, blue, or yellow), number (1, 2, 3, or 4), or shape (triangle, cross, star, or circle) - and they were also told that only one pattern was correct for each target card. The set of patterns is contained color, shape, and number, respectively, and is repeated twice. First, the color pattern was considered. After 6 correct consecutive responses, the pattern changed to the next pattern (shape). Therefore, this test was based on 6 correct answers to change the pattern of sorting cards. Each of the 60 cards was presented only once. The results were recorded when either the 60 cards have been exhibited (no matter how many the patterns have been completed successfully) or the participant has completed 6 categories successfully (no matter how many cards were left out).

Procedure

1) Adaptation tasks

At this stage, the updating tasks were programmed by a computer programmer based on the instructions. PHP programming language was used for the server-side, JavaScript and the jsPsych library were used for the client-side. The verbal sections and written explanations contained in the initial English language version were independently translated into Persian by the researchers and a specialist of the English language, and then, two translations were reviewed in a joint meeting and the problems were resolved and a single form was prepared. A Persian literature specialist, an English language specialist, and two psychologists reviewed the latest translated version, and the ambiguous and unclear sections were corrected. In the next step, the translated version was returned to English by an English language expert. After matching the translated version and the original one, the existing issues were resolved, and the test became ready to use. To investigate the rate of comprehensibility of the tasks' explanations in Iranian ethnicities, during a pilot phase, 100 individuals aged between 16 and 70 years (from four cities including Kerman, East Azerbaijan, Chaharmahal Bakhtiari, and Kurdistan), who were selected by convenience sampling, conducted the set of tasks. The pilot phase aimed to get feedback from the participants in different dialects on the comprehensibility of tasks' explanations and resolving possible ambiguities.

2) Psychometric characteristics

Psychometric characteristics of the tasks, including validity and reliability, were investigated. So as to examine validity, content validity, criterion validity, and discriminant validity were used. For this purpose, 406 normal individuals aged 16 to 70 years were selected, and the updating tasks were conducted in person at their workplace or their home. The WCST as an EF task was used to assess the criterion validity, and the correlation between this task and the updating tasks was studied. Additionally, 74 patients with different types of clinical disorders were studied to assess the discriminant validity of the tasks (11 TBI, 15 AD, 24 SC, and 24 MDD patients). Cronbach's alpha method and test-retest reliability were used to evaluate the reliability. Therefore, 100 normal participants were retested at 2- to 4-week intervals to determine the correlation of test-retest.

3) Comparison of the performance of normal individuals and patients with clinical disorders in the updating tasks

In this stage, the performance of healthy and patient participants, including SC, TBI, AD, and MDD, in the set of updating tasks was compared. To investigate this issue, 24 patients with SC who admitted to Shahid Beheshti Hospital of Kerman, 15 patients with AD who were in the nursing home, 11 patients with TBI who were introduced by a neurosurgeon, and 24 patients with MDD who were introduced by a clinical psychologist completed the set of updating tasks. The difference between the performance of patients and healthy individuals who were age- and sex-matched was assessed by multivariate analysis of variance (MANOVA). The timeline for data collection was from 2019 to 2021 for about 1.5 years.

Results

At first, descriptive data were reported from 406 healthy individuals (including 115 males and 291 females) and 74 patients (SC, SD, TBI, and MDD) in Tables 1 and 2.

Table 1. Frequency and percentage of sexuality in the healthy and patient groups

	Women		Men		Total	
	N	Percent	N	Percent	N	Percent
Normal	291	71.7	115	28.3	406	100
SC	5	20.8	19	79.2	24	100
TBI	4	36.4	7	63.6	11	100
AD	15	100	0	0	15	100
MDD	17	70.8	7	29.2	24	100

Table 2. Frequency and percentage of age in the healthy and patient groups

Age (year)	Normal		SC		TBI		AD		MDD	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
16-20	76	18.7	1	4.2	1	9.1	0	0	2	8.3
21-30	195	48.0	3	12.5	3	27.3	0	0	13	54.2
31-40	47	11.6	9	37.5	4	36.4	0	0	5	20.8
41-50	46	11.3	6	25.0	2	18.2	0	0	2	8.3
51-60	31	7.6	4	16.7	1	9.1	0	0	0	0
61-70	11	2.8	1	4.2	0	0	15	100	2	8.3
Total	406	100	24	100	11	100	15	100	24	100

In the next step, the psychometric characteristics of tasks were investigated. The Cronbach's alpha, which measured the internal consistency, and the test-retest correlation were used to evaluate the reliability of the set of tasks. A sample of 100 normal participants aged 16-60 years (M=33.71, SD= 12.60) was selected to reconduct the mentioned tasks at intervals of 2 to 4 weeks to investigate the reliability of the test-retest. The Cronbach's alpha and test-retest results are shown in Table 3. In the retest phase, the scores of some participants in some tasks were outliers, and during the screening phase, some of them were removed. Besides, some participants had less cooperation to do all tasks in the retest phase. Consequently, the sample size is different for each task.

Table 3. Cronbach's Alpha coefficients for the updating tasks

Task	Cronbach's Alpha	Test-retest
Keep track	0.65	0.71 (n=81)
Letter memory	0.97	0.82 (n=86)
Spatial 2-back	0.99	0.86 (n=89)
Spatial 3-back	0.98	0.81 (n=87)

In order to investigate the validity, content validity, criterion validity, and discriminant validity were used. The content validity of the tasks was assessed by two indicators of Content Validity Ratio (CVR) and Content Validity Index (CVI). The seven experts were required to evaluate each item of the updating tasks based on a 3-point Likert scale, including 'essential,' 'useful, but not essential,' or 'not necessary,' and the data collected from the experts' panel were analyzed using Lawshe's CVR method. According to all the experts' opinions, it was found that none of the sub-tests needs to be eliminated. Waltz and Bausell’s method was also used to investigate the CVI. Experts commented on the clearness, relevance, and simplicity of each task and classified them based on a 4-point Likert scale, including 1 (not relevant), 2 (somewhat relevant), 3 (quite relevant), and 4 (highly relevant). According to the experts, the numerical value for CVI and CVR is one, which is considered as good (30).

WCST was used to assess criterion validity. The method of investigating criterion validity was concurrent. The correlation between the number of correct responses of WCST and the number of correct answers in the updating tasks was as follows ($R_{(\text{WCST, keep track})}$ (406) = 0.22, $P \leq 0.001$, $R_{(\text{WCST, spatial 2-back})}$ (406) = 0.21, $P \leq 0.001$, $R_{(\text{WCST, spatial 3-back})}$ (406) = 0.30, $P \leq 0.001$, $R_{(\text{WCST, letter memory})}$ (406) = 0.14, $P \leq 0.001$). The correlation between the number of incorrect answers in WCST and incorrect answers in the set of updating tasks was as follows ($R_{(\text{WCST, keep track})}$ (406) = 0.25, $P \leq 0.001$, $R_{(\text{WCST, spatial 2-back})}$ (406) = 0.26, $P \leq 0.001$, $R_{(\text{WCST, spatial 3-back})}$ (406) = 0.30, $P \leq 0.001$, $R_{(\text{WCST, letter memory})}$ (406) = 0.18, $P \leq 0.001$). Even though the correlation between each mentioned task and the WCST score was significant, the correlations were low.

Then, the performance of healthy participants and patients with SC, MDD, TBI, and AD were compared. For this purpose, the normal individuals in terms of age and sex were matched to patients with clinical disorders. In Table 4, the mean and standard deviation (SD) of the scores of participants in each task are presented in healthy individuals and those with clinical disorders. As can be seen, the mean scores of patients with clinical disorders are lower in all updating tasks compared to normal individuals.

Table 4. Descriptive statistics for the dependent variables across the groups

Groups	N	Keep Track		Spatial 2-Back		Spatial 3-Back		Letter Memory	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
SC	24	16.59	21.72	38.77	22.36	37.77	17.40	5.39	7.70
Normal	23	73.60	10.41	75.63	13.31	71.50	13.28	64.73	16.78
TBI	11	50.33	19.21	62.34	24.93	60.96	22.36	33.58	31.09
Normal	11	77.43	7.37	79.34	5.49	78.51	5.12	74.36	16.32
AD	15	0.00	0.00	11.46	6.66	8.78	7.41	0.00	0.00
Normal	9	59.33	7.77	49.38	14.72	49.31	16.25	39.43	12.90
MDD	24	55.21	28.69	60.68	23.71	60.22	25.41	45.31	29.10
Normal	24	80.13	9.58	77.34	14.49	75.75	9.31	75.36	17.05

To analyze the data and to compare patients and healthy individuals, multivariate analysis of variance (MANOVA) was used, the results of which are shown in Table 5. As shown in Table 5, there is a significant difference between the studied groups in the updating-specific ability ($P \leq 0.05$). Accordingly, it can be suggested that in at least one of the mentioned tasks, there is a significant difference between normal individuals and patients with clinical disorders.

Table 5. Multivariate tests of dependent variables across the clinical and non-clinical groups

Dependent Variable	Value	F	DF1	DF2	P-value
SC					
Pillai's Trace	0.858	63.496	4.00	42.00	0.001
Wilks' Lambda	0.142	63.496	4.00	42.00	0.001
Hotelling's Trace	6.047	63.496	4.00	42.00	0.001
Roys' Largest Root	6.047	63.496	4.00	42.00	0.001
TBI					
Pillai's Trace	0.500	4.256	4.00	17.00	0.014
Wilks' Lambda	0.500	4.256	4.00	17.00	0.014
Hotelling's Trace	1.001	4.256	4.00	17.00	0.014
Roys' Largest Root	1.001	4.256	4.00	17.00	0.014
AD					
Pillai's Trace	0.986	333.48	4.00	19.00	0.001
Wilks' Lambda	0.014	333.48	4.00	19.00	0.001
Hotelling's Trace	70.208	333.48	4.00	19.00	0.001
Roys' Largest Root	70.208	333.48	4.00	19.00	0.001
MDD					
Pillai's Trace	0.314	4.918	4.00	43.00	0.002
Wilks' Lambda	0.686	4.918	4.00	43.00	0.002
Hotelling's Trace	0.458	4.918	4.00	43.00	0.002
Roys' Largest Root	0.458	4.918	4.00	43.00	0.002

Table 6 shows that there is a significant difference in each updating task between the normal and patient groups. As can be seen, performance of normal individuals was better than that of patients in all updating tasks, including keep track, letter memory, spatial 2-back, and spatial 3-back.

Table 6. Tests of between-subjects effects of dependent variables across the clinical and non-clinical groups

Dependent Variable	Sum of Squares	DF1	DF2	Mean Square	F	P-value
SC						
Keep track	38171.42	1	45	38171.42	129.70	0.001
Letter memory	41366.42	1	45	41366.42	246.20	0.001
Spatial 3-back	13358.01	1	45	13358.01	55.40	0.001
Spatial 2-back	15956.05	1	45	15956.05	46.61	0.001
TBI						
Keep track	4041.69	1	20	4041.69	19.08	0.001
Letter memory	9144.10	1	20	9144.10	14.83	0.001
Spatial 3-back	1695.24	1	20	1695.24	6.43	0.020
Spatial 2-back	1589.50	1	20	1589.50	4.87	0.039
AD						
Keep track	19798.05	1	22	19798.05	901.31	0.001
Letter memory	8747.29	1	22	8747.29	144.38	0.001
Spatial 3-back	9240.08	1	22	9240.08	70.52	0.001
Spatial 2-back	8090.21	1	22	8090.21	75.55	0.001
MDD						
Keep track	7454.818	1	46	7454.818	16.29	0.001
Letter memory	10838.735	1	46	10838.735	19.05	0.001
Spatial 3-back	2896.656	1	46	2896.656	7.90	0.007
Spatial 2-back	3333.500	1	46	3333.500	8.63	0.005

Discussion

This study aimed to investigate the reliability and validity of the set of updating tasks and to compare the performance of normal individuals and patients with clinical disorders (SC, AD, TBI, and MDD). One of the main differences between this study and previous researches was the use of a set of tasks that specifically was designed to measure the updating-specific ability (31,32).

The present study indicates that this set of tasks has acceptable reliability, according to the coefficients of Cronbach's alpha and test-retest correlation. As mentioned, Cronbach's alpha was higher than 0.7 for all tasks except the keep track task. In explaining this issue, it can be said that the keep track scale has dichotomous questions, and the results of Kuder-Richardson formulas (0.64) confirm the acceptable reliability of the task (33). The appropriate reliability of this set of tasks corresponds to the reliability of its original language counterpart in previous studies (34,35).

The results of the validation of this set of updating tasks indicated that they had an acceptable content, discriminant, and criterion validity, and the methods used to assess the validity were the same as previous researches (9). In the case of criterion validity, it can be noted that the WCST is not specific to measure the ability of updating and to measure all components of executive functions simultaneously and inseparably, so the low correlation between this task and the set of updating tasks was expected. Another possible explanation to consider is that the stimuli are streamed automatically in a fraction of a second in the updating tasks, and participants are asked to respond as quickly and accurately as possible, whereas the WCST stimuli are changed after the answer button is pressed by the participant.

The findings of this study indicate that there is a significant difference between the scores of healthy participants and SC patients in the set of updating tasks. Cognitive deficits are widely visible in SC (36), and it is stated that SC has a significant impact on people's updating ability. Furthermore, some cognitive impairments in the SC, such as deficits in working memory, are thought to reflect changes in the neural circuit of the dorsolateral prefrontal cortex (DLPFC). Gamma fluctuations in DLPFC are a neurological consequence of working memory function, and the strength of these fluctuations during working memory function in patients with SC is lower than in normal individuals (37). It is important to note that cognitive and executive functions are associated with the severity of symptoms in SC (38). In patients with SC, cognitive impairments are associated with longer duration of illness and greater negative symptoms. These cognitive deficits are associated with mental dysfunction in areas such as job performance, interpersonal relationships, and life satisfaction (38).

The results showed that the scores of TBI patients in the updating tasks were significantly different from normal individuals and were lower than them, which is consistent with the results of previous studies (31,39). TBI can negatively affect EF that plays an essential role in people's academic performance and social interactions. The frontal lobes' injury is the most common cause of executive dysfunction. Sometimes, damage to other areas which are connected to the frontal lobes can also be related to executive dysfunction. This issue is notable that frontal lobes are highly vulnerable to brain damage due to their location in front of the brain and their large size (40).

The results also showed a significant difference and poorer performance of people with AD in the updating tasks. This finding is consistent with the research background of deficits in executive function and working memory in patients with AD (41, 42). It is important to note that the most widespread form of dementia is AD, and it is a basal risk factor for death in these patients. In AD, executive functions are impaired from the early stages due to the destruction of the prefrontal cortex (43). Early detection of specific cognitive dysfunction can play a key role in limiting functional impairments in dementia through preventive or therapeutic interventions (42).

Finally, the results of assessing the scores of updating tasks for depressed and normal individuals indicate significant differences in the performance of healthy participants and patients with MDD. The performance of depressed participants was lower than that of the normal individuals, which is consistent with the results of previous research (44,45). Cognitive deficits are widely visible in MDD that can affect their activities of daily living. Neuropsychological assessments of depressive patients have shown poor cognitive performance. Depressed mood affects memory for reasons such as slow down thought processes, impairment in mental receiving and maintaining information, lack of focus on thoughts and feelings, and disability and fatigue in daily activities (32). Consequently, this psychomotor retardation can explain their poor performance in tasks that require speed of action.

Conclusion

According to the results of this study, it is stated that the set of updating tasks has acceptable validity and reliability. The findings of the comparison of healthy individuals and patients (with SC, MDD, AD, and TBI) performance indicate that there is a significant difference between their performance in the set of updating tasks. The lower cognitive performance in patients with mentioned disorders suggests that such diseases can affect updating-specific ability.

One of the main limitations of this study is that the coronavirus disease (COVID-19) pandemic limited our access to healthy and patient individuals and access to care centers of patients severely. As a result, the sample size of patients with clinical disorders in this study is relatively small. It is worth noting that future studies could use larger sample sizes for patients, as well as they could compare other disorders. In this study, only the updating component of executive functions was investigated. It is suggested that other higher-level executive functions can be examined in future research.

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