Research Paper: The Role of Neuropsychological Function Tests in Predicting Amnestic Mild Cognitive Impairment in the Elderly

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ABSTRACT

Background: Various studies have documented age-related changes in cognitive abilities and neural basis.

Objectives: To investigate the role of neuropsychological function tests in predicting amnestic mild cognitive impairment in the elderly.

Materials & Methods: In this cross-sectional study with a correlational design, the study population included elderly people over 60 years old residing in Bojnord City, Iran, in the spring of 2019. The participants were selected by cluster sampling method (n=128). The study instruments included the Bender-Gestalt test, Wechsler memory scale-revised, Wechsler adult intelligence scale third edition, and behavior rating inventory of executive functions. According to the scores of the elderly in the Wechsler memory scale (cut-off score=70), the participants were divided into two groups with amnestic mild cognitive impairment (MCI) and no MCI. For analyzing data, the discriminant analysis was performed using SPSS v. 23.

Results: Discriminant analysis showed that the obtained discriminant function had a significant diagnostic power (χ^2=166.001, P<0.0001) and 70% of the difference between the two groups with amnestic mild cognitive impairment and no mild cognitive impairment was explained by scores of fluid intelligence, visual-motor coordination, and executive functions. The predictor variables correctly classified 96.9% of the elderly in the groups of amnestic MCI and no MCI. Visual-motor coordination (coefficient=0.53) and fluid intelligence (coefficient=-0.54) were strong variables in predicting amnestic MCI.

Conclusion: Neuropsychological function tests can help predict amnestic MCI in the elderly.

Keywords: Cognitive dysfunction; Bender-Gestalt test; Intelligence; Executive function

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Highlights

● This study found that visual-motor coordination, fluid intelligence, and executive functions predict amnestic mild cognitive impairment.

Introduction

Mild Cognitive Impairment (MCI) is an intermediate state between normal cognition and dementia in which the basic activities of daily living are maintained. This term has been suggested as a diagnostic class to fill the gap between cognitive changes associated with aging and dementia-related cognitive impairment. Criteria of primary MCI include memory impairment, normal general cognitive function, maintaining activities of daily living, and lack of dementia [1].

Sometimes subtypes of MCI are determined based on the presence or absence of memory difficulties (amnestic vs. non-amnestic MCI). Individuals with amnestic MCI suffer only of memory loss while non-amnestic MCI is characterized by impairment in a single non-memory domain, such as executive functioning, language, or visual-spatial skills [2].

In 2017, 6.08 million Americans had MCI and 15 million people will suffer from MCI by 2060 [3]. MCI ranges from 6% to 12% in people over 60 years old [4] and MCI becomes dementia after 6 years [5]. Amnestic MCI as a precursor to Alzheimer Disease (AD) is more common than other types [6]. In Iran, the prevalence of AD was 2.3% in 2018 [7].

The cognitive deficits create several challenges for the elderly, their careers, and the health care system [8-10]. The elderly with MCI is characterized by memory problems [8, 11]. Identifying the role of neuropsychological factors in predicting amnestic MCI can be helpful in the timely diagnosis of cognitive deficits and the design of intervention programs.

Changes in visual functions are the first significant sign of AD [12]. A study has suggested that visual-motor coordination is an effective assessment in the diagnosis of AD and MCI [13]. Also, some studies found that the visual-motor disintegration was related to MCI [14-17]. With increasing age, adaptive visual-motor coordination (hand-eye coordination) decreases [18, 19]. In Iran, a study showed that the elderly with AD have poor performance on the Bender-Gestalt test in which higher rates of error are a sign of brain damage in these patients [20].

Memory deficits are associated with a decrease in fluid intelligence [21-23]. Fluid intelligence refers to the ability to reason and solve new problems [24]. Fluid intelligence is the ability to support adaptive, abstract, and flexible thinking [25, 26]. Injury to the prefrontal cortex generally causes deficits in tasks designed to measure fluid intelligence [25, 27]. Given the important role of the hippocampus in memory, some studies have suggested a positive association between hippocampus size and fluid intelligence abilities [28]. Results of a longitudinal study suggest that with increasing age in the elderly, the hippocampus volume and fluid intelligence scores decrease [29].

Executive functions are important abilities in the efficacy of older people's life. Executive functions are a set of skills such as problem-solving, attention, reasoning, organizing, planning, memory, inhibitory response, impulse control, set-shifting, and learning modification. As a result, deficits in these areas result in the inefficiency and inability of the elderly to perform daily activities [30]. Studies show that the performance in these processes depends on the function of the frontal lobe of the brain [31]. The volume of the frontal cortex decreases by 0.55% in each year, which is twice as much as of other brain regions [32]. The frontal and prefrontal areas appear to play an important role in goal-oriented cognitive functions such as executive functions [33]. Common complications of cognitive aging are dysfunction in cognitive executive functions including preservation, failure in initial, and inability to inhibit inappropriate responses; and difficulty in planning, and inability to problem-solve and working memory impairment [34-36, 23, 8].

Given the relationship between the cognitive conditions of the elderly with their quality of life [37], this study seeks to identify the role of neuropsychological factors in memory impairment of the elderly. Therefore, this study investigates the role of visual-motor coordination, fluid intelligence, and executive functions in predicting amnestic MCI of the elderly.

Materials and Methods

This is a cross-sectional study with correlational design. It was performed on elderly people living in Bojnord City, Iran in the spring of 2019.

The study population included all elderly people over 60 years old residing in Bojnord City. The participants were selected by the two-stage cluster sampling method. Two areas were randomly selected among 5 areas of the city. Then, in these two areas, two districts were randomly selected. The elderly who were willing to participate in the study were selected as the study sample (n=128) with 64 subjects in each group. Because of the correlational design of this study, G-Power software showed that the sample size was 100% sufficient.

Study Procedure

A clinical psychologist evaluated the exclusion and inclusion criteria for all participants. The inclusion criteria consisted of age over 60, the absence of psychotic disorders, and AD. The exclusion criteria included the diagnosis of AD, psychotic disorders, and age below 60 years. At first, the participants were evaluated individually with the revised Wechsler memory scale; the participants with two standard deviations below the mean were considered as having amnestic MCI (cut-off score of 70) [38]. Individuals with a score above 70 were also considered as having no MCI.

Subtests of the Wechsler adult intelligence scale (the third edition) consisting of digit span, similarities, picture completion, arranging images, block design, and integrating components were performed individually to obtain the fluid intelligence of the elderly. Bender-Gestalt test (the first version) was performed individually on the elderly to measure their visual-motor coordination. Relatives or caregivers of the elderly completed the reported inventory of behavior rating executive function.

The collected data were analyzed using a discriminant analysis test with the enter method.

Study instruments

Bender-Gestalt Test (BGT): The first version

This test was developed by Bender to measure visual-motor coordination. It contains 9 geometric images that participants should copy them onto a paper. Drawings are evaluated for accuracy, integrity, and integrity. The scoring method of Laks [38] was used which contains 12 key indexes of brain injury. These indexes include rotation, overlapping, simplification, fragmentation, retrogression, preservation, collision, impotence, closure difficulty, angulations, and cohesion. Laks determined the cut-off score of 5 for brain injury [39]. The degree of agreement among evaluators in the Laks's system was reported 0.95 to 0.98. The reliability of retest at intervals 3 to 12 months was reported as 0.57 to 0.63 in the elderly and 0.66 in patients with AD [40].

Behavior Rating Inventory of Executive Function (BRIEF)

This questionnaire is used to measure adults' executive functions in daily activities in a normal environment. It consists of 75 items that measure inhibition, shift, emotional control, self-monitoring, initiation, working memory, planning/organization, task monitoring, and organization materials. It is made of two indices of behavioral regulation and metacognition; the sum of which constitutes the global executive composite. The Cronbach alpha values of scales ranged from 0.73 to 0.9 with a global executive composite of 0.96. The test-retest reliability of scales over 4 weeks was in the range of 0.82 to 0.93 with a global executive composite of 94.4.

The inter-rater reliability of the scales was in the range of 0.44 to 0.68 for the entire index and 0.63 for the global executive composite. The internal consistency coefficients for inhibition (0.86), shift (0.99), emotional control (98.9), self-monitoring (0.35), initiation (0.81), working memory (79.9), planning/organization (0.77), task monitoring (0.88), and organization of materials (0.85) were calculated, too [41]. In the context of Iran, Mani et al. translated BRIEF-A and examined its psychometric properties [42]. Accordingly, they reported that Cronbach alpha of BRIEF-A subscales ranges between 0.65 and 0.83, and the correlation between subscales was in the range of 0.53 to 0.75 [42].

Wechsler Adult Intelligence Scale (WAIS-R): the third version

This scale measures intelligence and cognitive abilities. This study has used WAIS-R to measure fluid intelligence. According to Horn, we used subtests of digit span, similarities, picture completion, arranging images, block design, and integrating components to measure fluid intelligence [43].

The reliability of split half of the WAIS-R was 0.97 for total intelligence, 0.97 for verbal intelligence, and 0.93 for performance intelligence. The test-retest reliability

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coefficient with interval one to seven weeks averaged 0.97 for total intelligence, 0.97 for verbal intelligence, and 0.93 for performance intelligence [44]. In Iran, the test-retest reliability coefficient of the subtest was reported in the range of 0.58 to 0.87 and the reliability coefficient of intelligence coefficients in the range of 0.76 and 0.94 [45].

Wechsler Memory Scale: Revised

This scale is an objective memory to assess memory. It consists of subtests of personal awareness of everyday and personal issues, awareness of time and space, mental control, digit span, logical memory, visual memory, associative learning. According to Wechsler, the mean reliability coefficients among age groups for subtests and combina-

tions were from 0.41 to 0.90 with an average value of 0.74 and the reliability test-retest coefficients were satisfactory.

Reliability coefficients for the subscales ranged from 0.65 to 0.85 [46]. The agreement between the evaluators for the logical and visual memory subscales requiring clinical judgment was more than 0.85 [47].

Results

A total of 128 subjects with a Mean±SD age of 63.59 ± 6.59 (range: 60–82) years participated in this study. One hundred participants were female (78.1% and 28 male (21.9%). Also, 77 participants (60.2%) lived with their families, and 51 (39.8%) alone. In terms of education,

Table 1. Mean±SD of predicting variables in two groups with amnestic MCI and non-MCI

Predicting Variables		Mean±SD	
		Amnestic MCI	Non-MCI
Fluid Intelligence		72.29±11.58	98.61±16.62
Executive functions	Inhibit	4.69±2.93	3.26±2.74
	Shift	4.69±2.16	3.59±2.43
	Self-monitoring	6.06±2.45	3.34±2.95
	Initial	5.56±2.28	3.79±2.66
	Memory	5.62±2.66	3.65±2.81
	Planning	8.19±3.77	5.53±3.19
	Task-monitoring	4.37±2.66	3.15±2.29
	Organization material	2.19±2.39	2.98±3.43
	Emotional control	8.06±4.43	7.69±5.64
Visual-motor coordination		12.12±3.16	4.45±3.93

⊛CJNS

Table 2. The ability of each variable to distinguish between groups

Variables	Standardized Coefficients	Structure Matrix	Unstandardized Coefficients
Visual-motor coordination	0.741	0.547	0.208
Fluid intelligence	-0.268	-0.538	-0.024
Inhibit	-0.163	0.147	-0.058
Shift	-0.643	0.139	-0.279
Self-monitoring	0.791	0.293	0.291
Initial	-0.007	0.208	-0.003
Memory	0.421	0.211	0.154
Planning	1.100	0.222	0.315
Task-monitoring	-0.217	0.144	-0.087
Organization material	-0.586	-0.079	-0.198
Emotional control	-0.672	0.022	-0.133
(Constant)	-	-	-1.840

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ỳ= -1.84+0.20 (visual-motor coordination) -0.02 (Fluid intelligence) -0.05 (inhibit) -0.27 (shift) +0.29 (self-monitoring) -0.003

(initial) +0.15 (memory) +0.31 (planning) -0.08 (task-monitoring) -0.19 (organization material) -0.13 (emotional control)

Figure 1. Equation of discriminant function

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104 participants (81.3%) had lower education than high school, and 24 (18.7%) had a diploma or higher.

Allocation of subjects in each group was based on scores obtained in the Wechsler memory score (cut off =70) [38] and 64 subjects were in amnestic MCI and 64 subjects in the non-MCI group. Table 1 shows the mean and standard deviation of the predictor variables by groups.

Because there are two levels of dependent variables in this study, a function was obtained through discriminant analysis. The finding indicated that discriminant function had a significant diagnostic power (χ^2=166.001, P<0.0001) for the two levels of the criterion variable. The value of Wilks' lambda was 0.25 in which lower value relates to the more differences between groups (df=11, P<0.00001). The Eta-square value for discriminant analysis with the enter method was 0.70, indicating that the predicting variables can explain 70% of the discrepancy between the two groups of amnestic MCI and non-MCI. Functions at group centroids were -1.70 for amnestic MCI and 1.70 for non-MCI. That is if a person's scores are placed in the discriminant equation and the score is positive, the person belongs to the group of non-MCI and if be negative, the person belongs to the group of amnestic MCI. In the obtained discriminant function, the predicting variables correctly classified 96.9% of the individuals in groups of amnestic MCI and non-MCI.

As Table 2 shows, standardized coefficients, unstandardized coefficients, and structural coefficients are presented for the discriminant function. Standardized coefficients of the discriminant function are equivalent to regression coefficients (beta). These coefficients represent the discriminant weight of each variable in the group differentiation. The equation of discriminant function can be obtained by using unstandardized coefficients (Figure 1). Thus, the individual score is obtained by assigning each individual's score to each of the variables related to the function. Given functions at group centroids of amnestic MCI and non-MCI groups, if an individual's scores in variables are assigned to function and the score is negative, it is predicted that the individual will be one of the amnestic MCI group. Given the unstandardized coefficients and the constant number, following the prediction equation, the discriminant function is obtained.

The structural coefficients of the discriminant function are the correlation of each variable with the predicted score group or the discriminant score. These correlations similar to factor loadings are as discriminant loads and apply to group differences. Structural coefficients help determine the contribution of variables to group differences. In the discriminant analysis with the entering method, all variables were entered into the analysis and the results showed that the variables of visual-motor coordination, fluid intelligence, self-monitoring, planning, memory, initial, inhibit, and shift could significantly explain group differences.

Discussion

This study investigated the role of neuropsychological function tests in predicting amnestic MCI in the elderly. Although previous studies have uniquely examined the role of neuropsychological variables in MCI, this study investigated the contribution rate of several neuropsychological functions, including perception, motor, intelligence, and cognition in amnestic MCI. The results showed that predicting variables could explain 70% of the difference between the groups of amnestic MCI and non-MCI. In the obtained function, the predicting variables correctly classified 96.9% of the individuals in the group of amnestic MCI and non-MCI.

The strongest prediction was visual-motor coordination for group differences. The elderly in the group with amnestic MCI had errors such as rotation, overlapping, simplification, fragmentation, preservation, collision, impotence, closure difficulty, angulations, and cohesion. Likewise, Taeby et al. showed that the elderly with AD had poor performance on the visual-motor coordination [20]. In the Bender-Gestalt test, higher error rates indicate brain injury so that in this study errors of elderly in the amnestic MCI group had three times more than that in the non-MCI group.

In most studies, spatial-visual dysfunction has been found in MCI [14-17]. Serious changes occur in the perceptual-motor system with increasing age. Perceptual-motor adaptability and hand-eye coordination decrease with increasing age [18, 19, 48, 49]. Some studies have reported that changes in visual functions, particularly a decrease in motor visual integration, are the first significant sign of AD [12, 13].

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The results of this study showed that fluid intelligence is a strong predictor for membership in the group of amnestic MCI. This finding is consistent with studies suggesting that memory deficits are associated with impaired fluid intelligence [21, 22]. In this regard, studies indicate that in frontal patients, memory deficits are related to fluid intelligence [23]. Fluid intelligence is the ability to reason, flexibility, and new problem solving relating to prefrontal cortex function and damage to this area causes decreasing fluid intelligence [25, 27]. It seems that a decrease in fluid intelligence is associated with hippocampus atrophy. In this line, some studies showed that with increasing age in the elderly there is a decrease in hippocampus volume and fluid intelligence [28, 29].

Regarding the executive functions, this study found that self-monitoring, planning, memory, initiation, inhibition, task-monitoring, and shifting significantly predicted group differences. That is, the elderly with amnestic MCI have problems with executive functions. In this regard, studies have shown that patients with AD had problems in inhibition, memory, flexibility, planning, and problem-solving [9, 34-36, 50]. On the other hand, some studies have also suggested that executive functions are an important variable in predicting the conversion of MCI to dementia [51]. So, the elderly, who have planning difficulties for their daily activities, disability to initiate their daily activities, amnesia of the details, poor self-monitoring, ignoring the necessary preparations for problem-solving, disinhibition of irrelevant stimuli, and disability to shift attention from one task to another, are more likely to develop MCI and dementia in the coming years.

Previous studies that examined the role of executive functions in memory function have used neuropsychological tasks to measure executive functions. However, the strength of this study is the use of behavioral rating in daily performances to evaluate executive functions. Field studies also suggest that the elderly with MCI and dementia have difficulty in daily activities. So that deficits in memory and executive functions significantly predict dependency on others in daily activities [8]. This study has some limitations. The sample comprised healthy elderly and the criterion for the diagnosis of amnestic MCI was merely the scores obtained by the Wechsler memory scale. Next, the effect of demographic variables was uncontrolled on memory performance.

It is suggested that future studies examine neuropsychological function in predicting subtypes of MCI and determine the most vulnerable subgroups to AD. It is also suggested that longitudinal studies be conducted to identify which cognitive abilities can predict highly AD with increasing age and then to design rapid screening strategies of AD in the elderly.

Conclusion

This study indicated that visual-motor coordination and fluid intelligence are the strongest variables for predicting amnestic MCI. Also, executive functions in daily activities have a significant role in predicting amnestic MCI. Therefore, neuropsychological function tests can be a sufficient tool for the diagnosis of amnestic MCI. Given that some people with MCI develop AD over time, early diagnosis of MCI and its timely therapy can prevent the progression of Alzheimer disease.

Ethical Considerations

Compliance with ethical guidelines

This study with was approved in terms of ethical considerations in the Department of Psychology at the University of Bojnord (Code: 1318026). For ethical considerations, the participants signed a consent form to participate in the research and they were assured that their information would be kept confidential.

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