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The Relationship between Wisconsin Card Sorting Test and Raven Standard Progressive Matrices: A Latent Variable Analysis

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ABSTRACT

To investigate the relationship between the executive functions and the fluid intelligence, the relationship between two problem solving tests, namely the Wisconsin Cart Sorting Test (WCST, a widely accepted test of the executive functioning) and the Raven Standard Progressive Matrices Test (RSPMT, the most frequently used measure of the fluid intelligence) was analyzed by means of the relationship between the Structural Equation Models (SEM). 175 healthy university students participated in the study. RSPMT and WCST were used as data collection instruments. Significant correlations were obtained between the RSPMT`s total score, timing score and twelve different scores of WCST. Following the research hypotheses, the data obtained were analyzed by means of structural equation modeling. These findings further supported the relationship between the two tests. As a contribution to the literature, it was shown that besides updating and inhibition, set-formation is also significantly associated with fluid inteligence. The notion which proposes that the executive functions are the reflection of general intelligence and they represent the individual differences in the fluid intelligence performance has been supported with further scientific evidence.

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Keywords:
Executive functions, fluid intelligence, problem solving, WCST, RSPM, thinking, reasoning

Introduction

There has been a growing interest in executive functions. 'Executive function' is an umbrella term, and these consciously controllable brain functions are claimed to be the coordinators of the behavior when the intention is to reach a goal. The term 'executive function' was first introduced by Luria (1966; 1969; 1980) to isolate a particular set of brain functions. Luria described these functions emphasizing their controlling, programming and monitoring aspects and proposed pre-frontal cortex as the machinery for these higher-level cognitive functions. Further, Baddeley (1986) proposed 'central executive' as a controlling component of the working memory where executive operations are initiated, and the location of this construct was claimed to be the frontal lobes, more specifically the pre-frontal cortex. The term 'executive functions' was used by many researchers and a common element in their description can be pinpointed as 'goal oriented organization' (Anderson et al., 2001; Ardila, 2008; Banich, 2004; Delis, Kaplan & Kramer 2001; Elliot, 2003; Jurado & Roselli, 2007; Lezak, 1983; 2004; Pennington et al., 1996; Piguet et al., 2002; Stuss et al., 2001). Brain functions such as maintenance of an established behavioural set, cognitive flexibility, concept formation, abstract reasoning, planning, attentional filtering and preserving attention are often claimed to be the functions used for solving novel problems (Alvarez & Emory, 2006). Furthermore, some studies emphasized the importance of three executive functions: inhibition, shifting and updating. These functions are worth mentioning because they are working memory-related functions, and there is a rightful tendency to explain executive functions in relation to the working memory operations (Friedman et al., 2006; Miyake et al., 2000). Lesion and neuroimaging

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studies indicate that besides pre-frontal cortex, executive functions are also supported by sub-cortical structures and thalamic pathways. Although pre-frontal cortex acts as the primary neural substrate for these functions, they are not unique to this part of the brain (Alvarez & Emory, 2006; Koechlin et al., 2000; Monchi, Ko & Strafellab, 2006; Stuss & Alexander, 2000). Wisconsin Card Sorting Test (WCST) is one of the most efficient neuropsychological tests that is often used to assess executive functions (Alvarez & Emory, 2006; Jurado & Roselli, 2007; Roca et al., 2010). WCST measures shifting, which is one of the executive functions, as well.

Fluid intelligence is a concept in the Fluid and Crystallized Intelligence Theory developed by Horn and Cattell (1968). In this theory, the concept of crystallized intelligence represents the part of intelligence which is related to learned and acquired knowledge. Fluid intelligence, on the other hand, involves problem solving, adapting to new situations and conditions, discovering the web/pattern of relations in a problem, thinking logically, and reasoning correctly irrespective of the acquired knowledge. Also, fluid intelligence involves deductive and inductive reasoning. Carpenter, Just and Shell (1990) indicate that this form of intelligence which is also sometimes called analytic intelligence does not depend on the explicit knowledge acquired through education or past experiences; it involves resolving a new problem and the reasoning ability. It is maintained that fluid intelligence represents individual reasoning ability which is based on one's genetic traits, which coincides with Spearman's (1904) general ability factor (g factor) (Saggino, Perfetti, Spitoni, & Galati, 2006). Raven Standart Progressive Matrices (RSPM) test, one of the three versions of Progressive Matrices Tests (PMT) developed by John Raven, is also the most frequently used measure of fluid intelligence as a problem solving test (Carpenter, Just, & Shell, 1990; Raven, Raven, & Court, 2000). Neuroimaging studies show that fluid intelligence is specific to the lateral prefrontal cortex and the functions in the parietal region in the brain (Duncan, Burgess & Emslie, 1995; Gray, Chabris & Braver, 2003).

A problem occurs when there is an obstacle between the present situation and the target and when one does not know how to overcome this obstacle (Lovatt, 2002). In daily life, people frequently encounter some problems. Problem-solving ability enables one to reach the targeted aim successfully. It can be said that fluid intelligence has a significant role in problem-solving ability. Fluid intelligence is related to perception, attention, working memory and executive functions, which are called higher-level cognitive functions (Kafadar, 2004a & 2004b). It can be thought that there is a positive relationship between what we call "fluid intelligence" and such executive functions as abstract reasoning, intellectual flexibility, preventing the disruptive stimuli, maintaining the setup, and focusing and keeping attention. Furthermore, working memory, which has a significant role in the problem-solving process, has also an indispensable role, with regard to fluid intelligence, in the temporary storage, manipulation and update of knowledge, and in the production of a solution to a problem. It may be expected that individuals with low neuropsychological test scores will also score low on fluid intelligence test. Moreover, both fluid intelligence and executive functions are considered to be the cognitive functions specific to the prefrontal cortex in the brain (Duncan & Owen, 2000; Kafadar, 2012).

The key point for fluid intelligence and the executive functions is the problem solving capacity (Ardila, 2008). To be able to determine how related fluid intelligence and the executive functions are, we used two different problem solving tests to investigate the relationship between these two constructs. We wanted to answer the following questions: 1) How closely are these two constructs related or are they actually the same construct with different names?, 2) What is the role of the executive functions in fluid intelligence?, 3) Are there some other brain functions involved in fluid intelligence that are not executive functions? For this purpose, the relationship between WCST and RSPM was investigated although both are classified as problem solving tests. To our knowledge, these two tests have not previously been used jointly to investigate such a relationship. Discovering the correlations between these two tests may contribute to the literature through a better clarification of the relationship between the executive functions and fluid intelligence. In many studies conducted so far, it has been presented that fluid intelligence is related with updating and inhibition among the other executive functions (Curinella & Yu, 2000; Decker, Hill & Dean, 2007; Salthouse at al., 1998; Salthouse, Atkinson & Berish, 2003). On the other hand, it has been reported that shifting ability is not related to fluid intelligence (Friedman et al., 2006). The current study was conducted to analyse the different dimensions of relationships between these two concepts. For this purpose, the relationship between WCST and RSPM tests

was investigated through structural equation modelling. The current study is expected to contribute to the literature by testing whether there is a relationship between fluid intelligence and shifting.

Method

Participants

The study was conducted with randomly chosen 175 healthy university students (84 female (%47) and 91 male (%53)) who study in different departments in two public universities in Turkey, namely Abant İzzet Baysal University and Hacettepe University. Participation in the study was on a voluntary basis. Information about demographic features of the participants and state of health (whether they have a sickness or visual impairment, or whether they are taking a medicine which may affect their cognitive processes) was acquired via a Standard Data Collection Form. Subjects who reported a neurological or psychological illness were not included in the study. Before conducting the study, approval from Abant İzzet Baysal University Social Sciences Ethics Committee has been obtained. In addition, participants were informed about the context of the study.

Materials

Raven standard progressive matrices test (RSPM). RSPM, one of the three tests of Raven Progressive Matrices, consists of five sets as A, B, C, D and E. In each set, the participants are required to grasp the meaningless shapes, to determine the features of the shape that can complete the given system of relations, and to develop a systematic examination approach. By using five different sets, participants' ability to comprehend the valid principle and the relevant method is evaluated. There are totally 60 test items, with 12 items in each set. In each set, the level of difficulty in test items increases from set A to set E and from the first test item to the twelfth test item. In all test items, there is a shape, one part of which is missing, and there are choices to complete this missing part. The participants are expected to find the correct choice which can complete the missing part of the shape. The problem solving ability of the participants is tested through such a process. RSPM measures fluid intelligence, general ability, working memory and visual spatial screening. Time and total scores are obtained from the test (Raven, Raven & Court, 2000). RSPM reliability coefficient was calculated as .79 for the total score, and .64 for the time score. The validity studies showed that the test can be used for Turkish sample (Kafadar, 2004a).

Wisconsin card sorting test (WCST). WCST consists of two card packs having four Stimulus Cards and 64 response Cards in each. Each card is 7x7 cm, and there are various geometric shapes in different colours and numbers. The participants are expected to accurately sort every response card with one of 4 stimulus cards through the feedback (right or wrong) given to them based on a rule. Among various versions, the version of WCST with 128 cards developed by Heaton was used in this study. The test was applied individually and twelve scores were obtained (Heaton et al., 1993).

WCST is a neuropsychological test which is frequently used to measure such higher-level cognitive processes as attention, perseverance, working memory, abstract thinking, cognitive flexibility, and set shifting. It is particularly used in clinic field to identify the frontal region lesions and to measure the perseverative behaviors which refer to individual's insistence on wrong behavior. Moreover, to be able to change category, one needs to have high intellectual flexibility and ability in concept formation. A reliability study could not be conducted due to the nature of the test. The validity studies, on the other hand, were conducted both on sick and healthy groups, and it was shown that the test is valid for Turkish sample (Kafadar, 2004a).

Procedure

In this study, the Standard Data Collection Form was used in order to obtain demographic data about the participants. RSPM was applied in groups in class; WCST was individually applied in a quiet and isolated environment. In order to obtain information as to whether the participants satisfy the requirements to participate in the study, the questions indicated in the Data Collection Form were asked. Participants satisfying these requirements were included in the study. During test applications, nobody was allowed to enter the class. Test applications were conducted by an observer who previously received training in how to conduct the test. Test applications were individually conducted with the participant and observers sitting face to face around a table. Responses given to the tests were recorded in a standard registration form. Also, as required by the standard directives, scoring of each test was done by the researcher.

Results

Within the framework of the study, data collected from healthy participants were subjected to arithmetic average, standard deviation, Pearson product-moment correlation coefficient analysis and structural

equation modelling analysis. Descriptive statistical values obtained from RSPM and WCST were indicated in Table 1, and the correlation values among scores were indicated in Table 2.

Significant correlations were obtained between the time score and total score of RSPM, and the twelve scores obtained from WCST. Significant correlation coefficients vary between -.37 and -.15. Negative and significant correlations between perseveration scores and total reaction, total wrong and total right scores obtained from WCST and the total score of RSPM especially deserve attention.

Table 1. Descriptives statistics.

	N	$\overline{X}$	S.D.
RSPM Total Score	175	52.88	4.23
RSPM Duration	175	30.69	9.49
Number of Trials Administered	175	89.02	19.05
Total Number of Errors	175	19.01	13.42
Total Number Correct	175	70.02	8.86
Number of Categories Completed	175	5.80	.72
Perseverative Responses	175	10.38	8.68
Perseverative Errors	175	9.63	7.46
Nonperseverative Errors	175	9.38	7.05
Percent Perseverative Errors	175	10.12	5.43
Trials to Complete First Category	175	12.97	5.90
Conceptual Level Responses	175	65.96	7.87
Percent Conceptual Level Responses	175	75.62	14.65
Failure To Main Set	175	.53	.93

Table 2. Correlation coefficients between WCST and RSPM (n=175).

Scores	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. RSPM Total Score	—													
2. RSPM Duration	.12	—												
3.Number of Trials Administered	**-.37****	-.07	—											
4. Total Number of Errors	**-.36****	-.07	**.91****	—										
5. Total Number Correct	**-.28****	-.04	**.80****	**.44****	—									
6. Number of Categories Completed	**.15***	.05	**-.54****	**-.75****	-.07	—								
7.Perseverative Responses	**-.31****	-.02	**.77****	**.91****	**.28****	**-.78****	—							
8.Perseverative Errors	**-.32****	-.03	**.79****	**.92****	**.30****	**-.78****	**.99****	—						
9.Nonperseverative Errors	**-.33****	-.10	**.88****	**.92****	**.52****	**-.59****	**.68****	**.71****	—					
10. Percent Perseverative Errors	**-.33****	-.01	**.71****	**.86****	**.24****	**-.71****	**.94****	**.94****	**.64****	—				
11.Trials to Complete First Category	-.10	-.03	**.42****	**.46****	**.18***	**-.47****	**.38****	**.43****	**.44****	**.36****	—			
12.Conceptual Level Responses	**-.16***	-.01	**.36****	-.02	**.82****	**.35****	**-.20****	**-.17***	**.13***	**-.19****	**-**.06	—		
13.Percent Conceptual Level Responses	**-.26****	-.08	**-.76***	**-.84****	**-.36****	**.66***	**-.76****	**-.78****	**-.79****	**-.72****	**-.40****	.06	—	
14.Failure To Main Set	**-.15***	.02	**.62****	**.39****	**.72****	**-.32****	**.31****	**.33****	**.39****	**.26****	**.30****	**.60****	**-.29****	—

*p<.05, **p<.01

The statistical analysis was applied to the data in order to test our hypothesis with the help of a structural equation model. For this purpose, two structural equation models (SEM) were formed. Potential and observed variables were chosen based on the fit index value of the model. Various models were tested, and two models with the best fit value were chosen and proposed for the current study. The reason behind proposing two models is that thirteen different scores were calculated from WCST. In the first SEM, fewer WCST scores were entered into the analysis and better fit index values were obtained. Yet, the other scores obtained from WCST were entered into analysis through the second SEM, and it was intended to show the relationship between these scores and RSPM. The current study showed that the fit index values of the second SEM are relatively more acceptable compared to those of the first SEM. When the two models are compared, all the fit index values of the first model were found to be better than those of the second model.

In the first SEM, seven variables were included in the analysis as seven indicator variables (see Figure 1). Three latent variables predicted the seven indicator variables. These were predicted by the total number of reaction (WCST1) and the total number of error (WCST2) related to WCST, which is the latent variable defined as shifting.The total number of perseveration reaction (WCST5), total number of perseveration error (WCST6) and perseverative error percentage (WCST8) are related to the latent variable "intellectual flexibility". RSPM total score and total time predicted the latent variable defined as fluid intelligence (Gf). Coefficients between these indicator and latent variables were indicated in the SEM presented in Figure 1 ((Sümer, 2000).

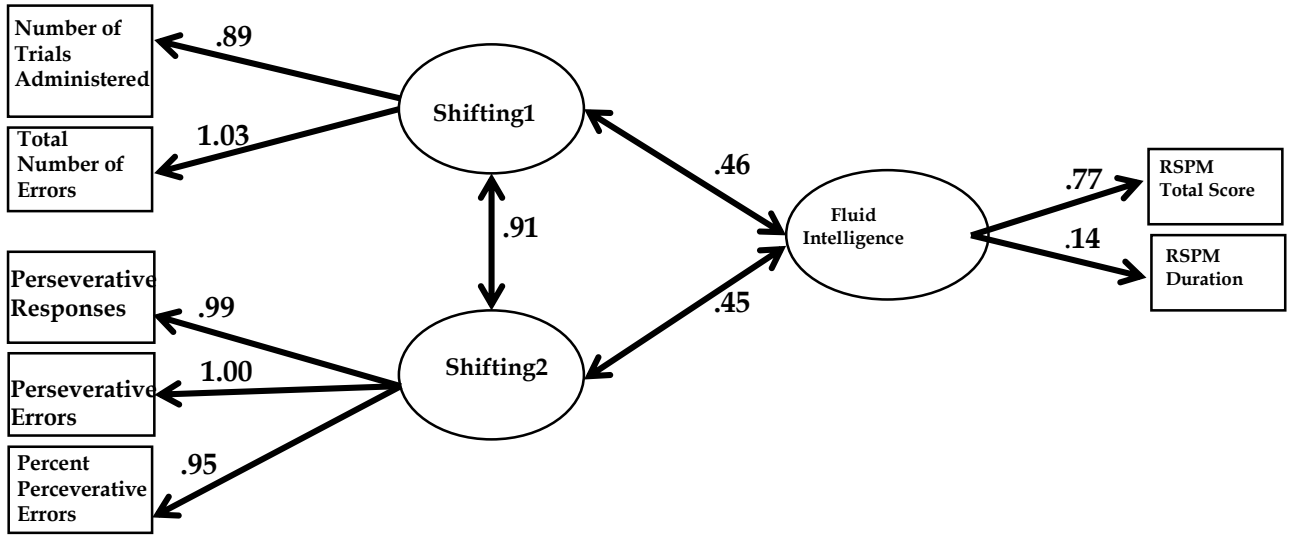


Figure 1. Structural equation model findings showing the relationship between RSPM and WCST.

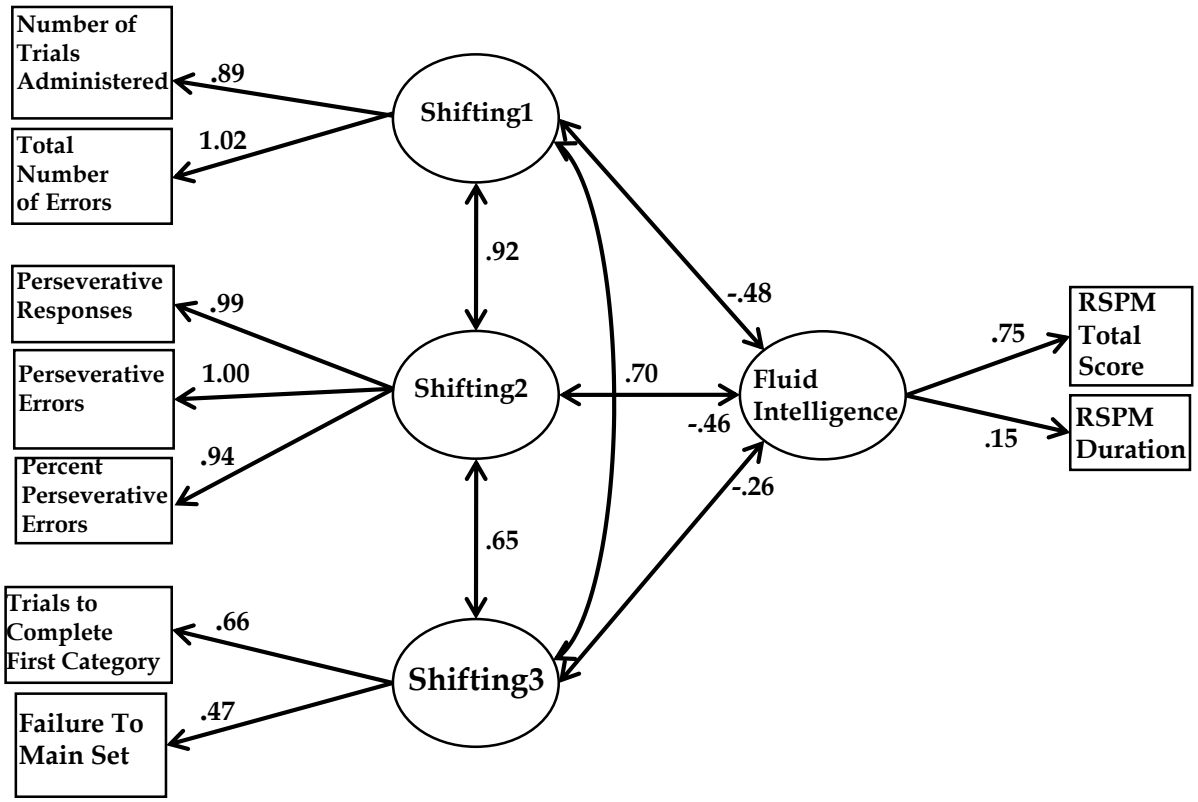


Figure 2. Second structural equation model findings showing the relationship between RSPM and WCST

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The fit value obtained from the SEM is as follows: X2=19.72, df=10, p=.032, X2/df=1.97, CFI=.99, RMSEA=.075, NFI=.98 PNFI=.35, PCFI=.35. The fit values reveal that the model fits the sample. In the second

SEM, two indicator variables were included in the analyses in addition to the previous seven indicator variables (see figure 2).

In the second SEM, two indicator variables were included in the analyses in addition to the previous seven indicator variables (see figure 2). The second SEM was conducted because of the 13 scores used in WCST. WCST is a neuropsychologic test in which 13 scores are calculated. With the second SEM, it was aimed to offer an alternative model. Yet, the first SEM fit values were calculated to be more acceptable compared to those in the second SEM. These are the number of reactions (WCST9) used for the completion of the first category and failure in maintaining the set (WCST12).

Discussion

In this study, we analyzed the correlations between the different executive functions and fluid intelligence. WCST is used to measure the executive functions. It assesses the concept formation, set shifting, set maintenance and cognitive flexibility (Solso, Maclin & Maclin, 2007). Number of Trials Administered and Total Number of Errors of the WCST evaluate the ability of concept formation. Perseverative reaction scores (WCST5, 6, 7, 8) evaluate mental flexibility. According to the findings obtained from our study, the cognitive processes measured by WCST are also closely related with fluid intelligence. RSPM, on the other hand, is the most frequently used test to assess fluid intelligence. 12 out of 14 scores obtained from two tests showed a negative and significant correlation. The findings revealed that there is a strong correlation between two tests. The results of the SEM analysis indicated that the data obtained from WCST and RPMT is in compliance with the model. Significant structural coefficients between indicator variables and latent variables were obtained. Furthermore, rather good fit values were obtained especially for the first model. The fit values of the second SEM were found to be at relatively acceptable level. Our findings are consistent with other research findings indicating a relationship between executive functions and fluid intelligence (Colom et al., 2006; Decker, Hill & Dean, 2007; Kafadar, 2012; Roca et al., 2010; Unsworth et al., 2009). The participants who obtained high scores at WCST achieved low scores in RSPM test, which indicates that the required key functions are the same, yet the participants were not able to use these executive functions dynamically.

As a contribution to the studies in the literature, this study shows that in addition to updating and inhibition, which are among the executive functions, set formation is also strongly related to fluid intelligence. The study conducted by Brydges et al. (2012) on children also indicates that there is a relationship between executive functions and fluid and crystallized intelligence. It was argued that this relationship could be explained with the fact that both fluid intelligence and executive functions are specific to the prefrontal cortex in the brain. It was maintained in a study conducted by Friedman et al. that updating, one of the executive functions, has a stronger relationship with fluid intelligence and crystallized intelligence, while inhibition and shifting functions have a less strong relationship with fluid and crystallized intelligence. However, the current study revealed that shifting component has a relationship with fluid intelligence as well.

WCST measures whether participants have mental setup, or set formation, that is, whether they can find the relevant rule, whether they can abandon the established rule and whether they are flexible enough to find a new rule (Solso, Maclin, & Maclin, 2007). Total reaction and total error scores in WCST evaluate mental setup, that is reasoning, while perseverative reaction (WCST5,6,7,8) scores evaluate mental flexibility, that is the inhibition ability. According to the findings of the current study, these cognitive processes measured by the WCST are also closely related to fluid intelligence. As stated in the literature, set formation in fluid intelligence which is considered equivalent to problem solving ability, or finding the rule by analysing the features of the target problem mostly without the pre-learned knowledge, is an important cognitive component to reach the correct result (Carpenter, Just & Shell, 1990). Moreover, inhibiting the irrelevant stimuli during the problem-solving process and applying the rule that is considered correct until a solution is reached are important components with respect to fluid intelligence. It is believed that focusing on problem-solving ability during the process and maintaining the process until the end are necessary to reach the targeted behavior successfully. Updating, that is working memory, also accompanies this process from the beginning till the end. As a result, it is believed that all the components of executive functions have a relationship with fluid intelligence. These mental functions constitute the similar features of executive functions and fluid intelligence. The fact that the participants who received a high score from WCST scored low in RSPM makes one think that these participants could not manage the processes discussed above dynamically.

Sternberg (1985) argues that executive functions are the reflection of general intelligence or g factor, which represents the individual differences in the executive functions. In a study conducted by Unsworth et al. (2009), a relationship was found among executive functions, fluid intelligence and various personality traits. This finding is consistent with what Sternberg (1985) proposed. In another study by Carpenter, Just and Shell (1990), it was argued that the main difference between the participants who received high or low scores from RSPM arises from the way the rules of the problems in the test are separated into small pieces. Participants find the correct choice by comparing the components of the rules of the problem. It is thought that this process corresponds to shifting, one of the executive functions. The main difference between the participants who received high or low scores from RSPM arises while finding and analyzing the rule, which affects the rate of making errors. It is believed that further studies may be conducted to examine the relationship among executive functions, fluid intelligence and personality traits, and that these studies may make a significant contribution to the field.

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