Cognitive Model of Problem Solving

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ABSTRACT

Objective: In this study, problem solving regarded within cognitive psychological literature and the relationship of cognitive stages of problem solving with various cognitive processes is studied in a theoretical frame. In the study the pattern of problem solving with reasoning, attention, working memory, planning, making strategy and relation pattern is tried to be explained with a model.

Method: The study is composed of two stages. In the first stage, RSPM: Raven Standard Progressive Matrices (RSPM) was applied to the subjects. In this first stage subjects are expected to write down the mental stage they perform while solving the test substances in the RSPM test. In the second stage 6 neuropsychological tests were applied on the subjects who are university students.

Findings: Findings of the study were analyzed by using Structural Equation Modeling (SEM).

Discussion and Conclusion: Two dimensional models were tried to be formed in order to explain the relation pattern of neuropsychological tests among each other. In this model the first dimension shows the problem solving stages within mental processes of a healthy person; the second stage shows the relationship between problem solving, reasoning, abstract thinking, and selective attention, continuous attention, working memory, planning and making strategy. Findings were discussed under the light of related literature.

Keywords: problem solving, problem solving stages, executive functions, fluid intelligence, cognitive flexibilty, reasoning

ÖZET

Problem Çözmenin Bilişsel Modeli

Amaç: Bu araştırmada bilişsel psikoloji literatüründe ele alınan problem çözmenin ve problem çözmenin bilişsel aşamalarının çeşitli bilişsel süreçlerle olan ilişkisi, kuramsal bir model çerçevesinde ele alınmaktadır. Araştırmada problem çözmenin, akıl yürütme, dikkat, çalışma belleği, planlama, strateji kurma ile ilişki örüntüsü bir modelle açıklanmaya çalışılmıştır.

Yöntem: Katılımcılar üniversitenin çeşitli bölümlerinde okuyan sağlıklı üniversite öğrencileridir. Araştırma iki bölümden oluşmuştur. İlk bölümde, 250 katılımcıya Raven Standart Progresif Matrisler Testi (RSPM) uygulanmıştır; daha sonra deneklerden RSPM testinde yer alan test maddelerini çözerken, hangi zihinsel aşamaları gerçekleştirdiklerini Sözel Protokole yazmaları istenmiştir. İkinci aşamada ise 78 gönüllü katılımcıya Wisconsin Kart Eşleme Testi (WCST), Londra Kulesi (LK), Stroop Testi, İşaretleme Testi (İT), Karmaşık Uzam Görevi (KUG) ve Görsel Bellek Uzamı (GBU) uygulanmıştır.

Bulgular: Araştırmadan elde edilen bulgular, Yapısal Eşitlik Modeli (YEM) kullanılarak analiz edilmiştir.

Tartışma ve Sonuç: Uygulanan nöropsikolojik testlerin kendi aralarında oluşturduğu ilişki örüntüsünü, açıklamaya yönelik iki boyutlu bir model oluşturulmaya çalışılmıştır. Bu modeldeki birinci boyut, karşılaşılan problem durumunda sağlıklı bir insanın, problemin çözümüne yönelik olarak zihinsel süreçlerinde gerçekleşen aşa-

maları; ikinci boyut ise problem çözme, akıl yürütme, soyut düşünme, seçici dikkat, sürekli dikkat, çalışma belleği, planlama ve strateji kurma arasındaki ilişki örüntüsünü göstermektedir. Elde edilen bulgular, ilgili literatür ışığında tartışılmıştır.

Anahtar Kelimeler: problem çözme, yönetici işlevler, problem çözme aşamaları, akıcı zekâ, zihinsel esneklik, akıl yürütme

INTRODUCTION

One of the subjects of cognitive psychology which tries to understand and explain mental/cognitive processes and put forward the relationship between them is problem solving. How and where to park a car in a parking lot, how to solve a math problem, the strategy to be followed in a chess game, how to plan business-life or to form research pattern for a scientific study are the behaviors that are all related with problem-solving. Problem solving is involved in every kind of activity of people's daily and professional life; it is the common component of wide and different fields such as education, science, law, sport, medicine, industry, literature etc. (Jonassen 2000).

Problem solving requires searching a rule, plan or strategy which helps us to reach the aim that is unattainable currently. Problem solving requires three conditions: first one of them is the beginning period, which is thinking on an open problem, directing the behavior clearly to the aim. The second process includes the trial of various rules and strategies for solving the problem; sub-goals according to the quality of problem are determined, processes in order to determine these sub-goals are carried out. Solving the whole problem depends on sequential operation of these processes. The third one is target status and it is composed of achievement (Plotnik, 2009). It is thought that a sequence of problem solving is needed to attain objective solution from target problem situation and a sequence of mental process such as reasoning, abstract thinking, mental flexibility, working memory, focused and continuous attention, strategy making is required simultaneously.

Problem Solving and Other Cognitive Processes

Pioneers of problem solving are Gestalt psychologists (Ellis and Hunt 1993, Solso et al. 2007). Gestalt psychologists asserted that there is an interaction between perception and memory, when the problem is regarded with different points of view, the solution can be found with a momentary insight or realization. The first researchers to explain problem solving process with data processing approach are Newell and Simon (1972). With a computer simulation program they have developed, researchers expected participants to think aloud while solving a difficult problem. In this way, they have analyzed how the participants verbally evaluate cues to form a strategy. They have asserted that thinking processes that are related with problem solving process are composed of two stages; these are realization of process and research of process. In his study, Sweller (1988) developed a scheme which he named as purpose-result analysis and expressed that specific cognitive processes such as working memory, selective attention are needed for solving problem.

There are few studies about the specific cognitive structure which operate in problem solving process (Solso, et al., 2007). In the internal representation model developed by Eisenstadt and Karaev (1975) it is shown that internal representation of problem analysis is formed with an active research. In this process which is called as top-down analysis; analysis begins with a hypothesis and hypothesis is tried to be confirmed by searching stimuli in the outer world. Another possibility is bottom-up analysis. Here the stimuli are observed and then matched with structural components. Formation of internal representation depends on subjective representations which are stored in memory as an active process. Placement of image parts of problem field, within internal representation automatically activates planning processes which are bottom-up. Detecting which parts are in this form is top-down analysis. People follow a research strategy which deepens gradually. These imaginary moves may cause working memory to overload in short-time. Internal representation model asserts that specific cognitive processes such as planning, strategy making, and memory contribute problem solving process, tries to explain analysis process and draws a general frame about the basic mechanisms of problem solving.

In a broad study carried out by Carpenter, Just and Shell (1990); a theoretical model that would explain problem solving process used in Raven tests in details was tried to be developed. As a result of the study carried out in three stages; it is asserted that subjects first of all identify the rules within problem; in this stage they separate each rule into small fractions. In this way subject find the true answer by comparing the components within the problem. Individual difference between subjects which show high and low performance in the test occurs in the process of separating into small parts, this

process influence the rate of subjects' doing wrong. In the second stage of the research, the relationship between Raven tests and Tower of Hanoi test which measures cognitive processes was observed. As a result of correlation analysis, a meaningful correlation coefficient was determined between the numbers of total errors of both tests. According to researchers, this finding shows that purpose repetition strategy which is included in Hanoi Towers is valid for Raven tests. At this stage, it was shown that ability of purpose repetition strategy is related with working memory; the purpose towards problem solving behavior was formed and sustained in working memory. In the final stage of research two computer simulation model called Betteraven and Fairaven in which the skill of purpose management in working memory will be used to a great extent were used. Findings have put forward that subjects' regularly repeating coding and inductive strategy enable an increase in their operation characteristics. Difference between individuals in operation process occurs first of all in inductive skill of abstract relations and dynamic management of working memory for solving a sequence of problem.

In a study carried out by Kafadar (2004a and 2004b), relation between fluid intelligence RSPM (Raven Standart Progressive Matrices) and tests groups composing of WAIS-R (Wechsler Adult Intelligence Scale-Revised), WCST (Wisconsin Card Sorting Test), CST (Complex Span task), Stroop test TBAG Form and VADS-B (Visual Aural Digit Span). 85 subjects in total participated in the research, findings that support the relationship between RSPM which measures problem solving and administrative functions, digit span, working memory and selective attention were obtained (X2 (160, N= 85) =127.21 p<0.23 , RMSEA = 0.032, GFI =0.84, AGFI=0.78, CFI= 0.96, NNFI=0.96). Two-dimensional model was suggested according to research findings. In the first dimension of this model, stages of cognitive processes that occur in fluid intelligence in case of problem were given. In the second dimension, their relations with hypothetic cognitive structures which are thought to be related with these stages were shown.

In a field which is called cognitive informatics and aims the explanation of human's data processing and natural intelligence with engineering applications Wang and Chiew (2010) presented mathematical and cognitive model of problem solving process. Cognitive process of problem solving starts with the identification of object. Later on, determination of features, alternative aims and choices are reasearched and quantified; with the evaluation of results, selection, satisfaction level of result, forming reaction and storage of knowledge into memory the process is completed. With the findings of study of Wang and Chiew (2010) asserted that they have explained cognitive structures (perception, memory, learning etc.) and representation mechanism of internal knowledge in the basis of problem solving cognitive process. In the model called layered reference model of the brain developed by Wang et al. (2006) problem solving is at the seventh stage being higher-level cognitive process and is interaction with cognitive processes such as learning, attention, memory types, abstract thinking etc.

RSPM which is applied to individual or to group is one of the three forms of RPM (Raven Progressive Matrices) and can be used for the evaluation of children, elderly and patient population and personnel choice to a great extent for requiring verbal process at the lowest levels (Carpenter et al. 1990, Raven et al. 2000, Oakland 1995).

RSPM which is a general proficiency test is composed of 60 problems in total each including 12 test substances in each set which are named as A, B, C, D and E sets. In each test substance a problem figure which lacks a part and options for the lacking part were given. While each set gradually gets difficult from the first test substance, tests gets difficult as well from A set to E set. In each test the subject has to determine shape characteristics that will complete relations system by comprehensing the meaningless shapes within test substance and develop a systematic reasoning method. In the test, by using A, B, C, D and E sets which include different function, individual's ability of comprehending valid principle and related method is evaluated. In this way, it is required for individual to form new thinking styles and new working approaches. RSPM which is used to measure regular thinking and analysis also evaluates mental ability or speed of activity (Raven et al. 2000, Raven 2000). RPM which is a classical analytic intelligence test gives information about other cognitive processes as the way in problem solving. The structure of problems in RPM requires forming an analytical strategy. The test includes abstract reasoning, induction and deduction (Carpenter et al. 1990, van der Ven and Ellis 2000, Zook et al. 2004).

RPM tests are used commonly today in order to measure fluid intelligence part of Fluid and Crystallized Inteeligence Theory developed by R. Cattel (1963). There are studies in the literature upon the fact that there is a relationship between RPM and working memory, reasoning and executive functions (Ackerman et al. 2002, Carpenter et al. 1990, Colom et al. 2004, Colom et al 2003, Engle et al. 1999, Kane et al., 2004, Kafadar 2004a, 2004b, 2010, 2011, Necka 1996, Roberts et al. 1991, Roberts et al. 1988, Stankov et al. 1994, Unsworth and Engle 2005, Schweizer et al. 2005, Verguts and De Boeck 2002). In the

current study RSPM which is one of RPM tests was regarded as a problem solving test and since it is thought to have relation with problem process cognitive processes were observed in a single study and its contribution to problem solving was tried to be determined.

Stages of Problem Solving

Apart from the relationship with other cognitive processes, problem soving should also have stages. What are the stages of problem solving process from the recognition of problem as a stimulus to reaching solution? Sometimes the duration of solving problem takes minutes sometimes days, weeks or even months. The process generally operates unconsciously and these stages are generally hidden while solving daily problems (Solso et al. 2007). Psychologists have defined various stages for the solution of problem. Ellis and Hunt (1993) mention three stages in problem solving process. These are recognition of problem, forming alternative hypothesis for the solution and choosing one of them, valuating the solution and testing. Heyes (1989) expresses that there are six sequential stages in problem solving: (1) Defining the problem, (2) representation of problem, (3) planning the olsution, (4) application of the plan, (5) evaluation of the plan, (6) evaluation of the solution. De Groot mentions four stages: Situation assessment, developing a plan draft, renewal or change of inadequate plan draft and control of the solution (Shallice 1988).

In order to find problem solving stages in the current study, insight technique which was used by European psychologists for the first time in 19th century was used. This technique is very suitable for problem solving researches. It is believed that written or verbal expression of thinking would enlight the mechanism about thinking processes. During problem solving, participants mentioned the thing they deal, their intent, the situation they perceive at that moment, the thing they try to overcome and talked about their attempts of problem solving (Carpenter et al. 1990, Newell and Simon 1972, Solso et al. 2007). In this study, the participants were firstly given a problem, and then they are expected to write how they solved this problematic situation and how they have reached the solution in stages.

Purpose

This study was based on studies carried out by Carpenter, Just and Shell, (1990) and Kafadar (2004a, 2004b). In the first stage of the study which is composed of two stages; the stages of problem solving process, in the second stage determination of cognitive process that would be related about problem solving process and explanation of these relations in a theoretical frame was done. In thsis way, it was aimed to understand the way of brain's operating during problem solving process, and contribution would be provided to literature about the relation of cognitive processes that are thought to be related with problem solving process of a healthy person. Neuropsychological tests were used as assessment instrument. These neuropsychologist tests are; RSPM, WCST, Complex Span Task, Mesulam's Cancelletion Test, Stroop Test, TOL and Spatial Span. In addition to this, Verbal Protocol was used as well in order to understand the cognitive stages about problem solving process. In the current study it was planned to use structural equation modelling which is very sitable for statistical testing of mathematical relationshio among cognitive processes was used. ın the study it was aimed to determine the relation pattern of tests which assess different cognitive functions and predictability of points, describe subject relations in the frame of a model.

METHOD

Participants

The study is composed of two parts. In the both parts, healthy university students participated as subjects in the study. All the voluntarily participants of the study are composed of 2. and 3. class students of Abant İzzet Baysal University, from different departments and branches. In the first stage 250 volunteer participants were applied RSPM and Verbal Protocol in groups. Then 78 participants from the whole who want to be involved in the second stage voluntarily were applied other neuropsychological tests individually. Of all the 78 participants, 45 of them are female, 33 are male, 92% of them are right-handed and the age average is 20.80 (ss:±1.57). All subjects gave informed detailed explanation about the study. Social Sciences Human Research Ethics Committee permission was based for study.

Materials

Information Collection Form: With a standard data collection form, information about demographic features of participants, their state of health (whether they have an illness, they are on medication, whether they have visual impairment or impairment about color separation) and their handedness. It was paid attention that participants of the study do not use any medication that would influence cognitive processes. In this sense, those who have neuropsychologists or psychiatric disorder, who ose medication that influence cognitive processes or have used it for long time before were not included in the scope of study.

Verbal Protocol: In the study, verbal protocol was

used in order to detect cognitive operation steps that participants follow during problem solving. In this aim, participants were first of all applied RSPM test, then they were informed that the test they are given is a problem-solving test and they were expected to write down open-ended how they solved the problems in the test. At this stage, it was aimed to determine their problem solving stages. Verbal protocol was applied on participants in groups.

Raven Standard Progressive Matrices Test (RSPM): RSPM which was developed by Raven is composed of five sets; A, B, C, D and E and there are 60 test substances in total, being 12 in each. RSPM was applied to participants in groups (Raven, Raven, Court, 2000). The tests assess problem solving skill.

Wisconsin Card Sorting Test (WCST): WCST is composed of two card desks; each having 4 stimulus cards and 64 response cards. In each of WCST card, there are shapes in different numbers and colors. What the participant should do is to match stimulus and response cards with each other according to a specific rule (Heaton et al. 1993). The test which is calculated with 13 points, measure perseveration and reasoning, abstract thinking, mental flexibility and complex attention skill.

Mesulam Cancellation Test (CT): There are four forms of CT organized on A4 paper (Mesulam 2004). These are organized as 4 sub-tests being regular letters, irregular shapes, irregular letters and irregular shapes. There are regularly and irregularly organized letters and shapes on A4 form paper of each sub-test. What the participant should do is to cancel the target letter or shape given in each form as quickly as possible. Points are assessed in the test as target number cancelled, target number cancelled wrong, target number skipped and duration. The test measures continuous attention.

Stroop Test: Stroop test includes expression of the name of colors which are painted in different colors. The test is composed of fice white papers in 14x21.5 cm. There are lines composed of 4 subjects given randomly. These cards are 'stimulus' substances of test and the reaction participants should give towards these stimuli form the sections of test. Basic points of the test are attained by scoring the sections separately. For the five cards of the test; total duration, error number and points of correction number are assessed. The test measures focued attention, speed of data processing, skill of sustaining the task under destructive effect.

Tower of LondonDX (TOLDX): test is composed of two matched wooden towers, one for participant and the other for tester. There are three sticks on wooden towers. The longest stick can take three bead, medium one takes tow and the shortest one takes one bead. Upon each wooden tower there are three beads in different colours; blue, red and green. The purpose is to string beads as it is shown with the least move. The test measures the skill of planning and forming strategy (Atalay ve Cinan 2007, Culbertson and Zillmer 2005).

Complex Span Task (CST): In the study Complex Span Task was used in order to measure the capacity of the working memory. Participant is given 1 point for the attempt he remembers coorectly and total sum of these correct attempts makes the score of participant. Sentence digit span task and Operation-word span task among CST were used in this study. In the task of sentence-number span, the participant is expected to read aloud the sentence and the number in the box at the end of sentence and then to keep the number in mind. In the tasks of complex span, the number of number to be kept in mind and words increases. At the end of each row, the participant is required to remember and say the numbers in boxes. In the task of operation-word span, participants are expected to read aloud mathematical operations and symbols and keep the numbers in box at the end of operation. Computer version of CST was used (Kafadar 2004a, 2004b).

Spatial Span: The test which is one of the sub-tests of Wechsler Memory Scale – III is composed of two sections being forward and backward touching. In each section participant watches your touching 3D squares on increasing rows, then he repeats this process forward and backward (Spatial Span forward or backward). Organization of 3D squares is the same in both Forward Visual Memory Span and Backward Visual Memeory Span. The score of participant is composed of the total sum of scores achived in each subject. The test measures mental rotation (WMS-III 2002).

Procedure

In the study, 7 neuropsychological tests, Verbal Protocol and Standard Data Collection form were used as assessment tool. Participants were given form in the classes at Abant İzzet Baysal University Campus. After necessary permissions were taken, students were informed briefly about the research and the test was applied on those who voulunteered in the research. The research is composed of two stages.

Stage 1: First of Verbal Protocol was applied with RSPM test to many participants in classroom environment. After necessary explanations about the research are given, participants were initially expected to solve test substances included in RSPM test and each requiring the solution of a problem. Those who have finis-

hed RSPM test were given gthis instruction: "the test you have been applied was e problem-solving test. We would like to know which solution ways you follow in order to solve each problem in the test. For this reason please first of all think about the stages you have followed for solving the question. Then write down these stages below in order and by giving numbers". Here the participants are expected to write down how they have solved problem substances given in RSPM test. In this way it was aimed to determine the stages occur during problem sovlving process with nsight technique. At this stage of the study 250 participants were applied RSPM and verbal Protocol.

Stage 2: 78 participants from the whole who want to be involved in the second stage voluntarily were applied 6 neuropsychological tests individually.

Participants were asked questions in Data Collection Form in order to be informed whether they meet the requirement to be included in the research. Participants who meet these criteria were included in the research.

Test application was done by a tester who has been educated on this subject before. Test applications

Table 1. Descriptives statistics

Neuropsychologic Test Scores	N	Minimum	Maximum	Mean	S.D.
Raven Standart Progressive Matrices Test					
Total score	78	42.00	59.00	51.79	4.13
Total duration	78	13.00	80.00	29.52	9.27
Wisconsin Card Sorting Test (WCST)					
Total Number of Trials (WCST1)	77	69.00	128.00	93.06	19.84
Total Number of Errors (WCST2)	77	6.00	66.00	22.29	15.27
Perseverative Responses(WCST5)	77	3.00	48.00	12.51	10.39
Perseverative Errors (WCST6)	77	3.00	44.00	11.70	9.12
Percent Perseverative Errors (WCST8)	77	4.05	34.37	11.77	6.60
Tower of London^{DX} (TOL)					
Total Correct Score	78	.00	10.00	4.46	2.43
Total Move Score	78	.00	79.00	30.23	17.95
Complex Span Task					
Sentence Digit Span Task	78	2.00	13.00	8.00	2.44
Operation-Word Span Task	78	2.00	12.00	5.37	1.88
Spatial Span					
Forward	78	5.00	14.00	9.47	1.91
Backward	77	5.00	26.00	9.35	2.61
Stroop Test TBAG Version					
Stroop Task Name Figure the İnk Color Duration	78	6.00	21.00	9.85	2.22
Stroop Task Name Neutral Words the Ink Color Duration	78	8.00	24.00	11.93	2.851
Stroop Task Name the İnk Color Duration	78	9.00	34.00	18.33	4.95
Mesulam's Cancellation Test					
Structured Letters Total Duration1	77	.58	131.00	83.95	21.58
Structured Shapes Total Duration2	78	.52	127.00	81.80	21.64
Random Letters Total Duration3	78	.51	140.00	82.57	25.37
Random Shapes					
Total Duration4	78	.44	135.00	61.96	27.61

were carried out individually around a table where the participant and tester sit face to face. During test application nobody was allowed to enter the room. Applications of the test were carried on a single seesion. The order of tests for each participant was determined according to total balance technique. According to this, the order of application of tests changed for each continuous participant. Reactions towards tests were recorded in standard registration forms and scoring of each test was carried out by researcher according to standard instructions.

FINDINGS

In this section, findings of the study carried out in two sections were presented. Due to the nature of data obtained from Section 1, any statistical analysis could not be done. Open-ended problem solving stages written by participants was subjected to content analysis by the researcher. As a result of content analysis, it was seen that obtained data can be listed in three groups. These three groups formed consecutive three stages about problem solving stage. Descriptive statistic data calculated about data obtained from 6 neuropsychological test practices in Section 2 was presented in Table-1. According to this, number of participant (N), minimum maximum, mean and standard deviation values were shown about the points calculated from 6 neuropsychological tests.

Of the entire neuropsychological test points, those hich give the most meaningful model relation were included in structural equation model. Analysis results show the compatibility of data to sampling(X2 (N=78)=218.85, DF=143, P=0.000, X2/DF=.53, NFI=0.85, CFI=0.94, PCFI=0.64, RMSEA=0.083) (Figure-1). In the model, problem solving latent variable was predicted by mental rotation, working memory, reasoning, mental flexibility, focused attention, continuous attention and planning latent variables. In order to follow correlation coefficients which are among latent variables more easily they were given in Figure 1 but were presented separately in Table-2.

DISCUSSION

Findings obtained from SEM analysis which was carried out with data of the research show that data is compatible with sampling and adjustment analysis results show that suggested model is supported (Figure-1 and Table2).

Cognitive Model of Problem Solving

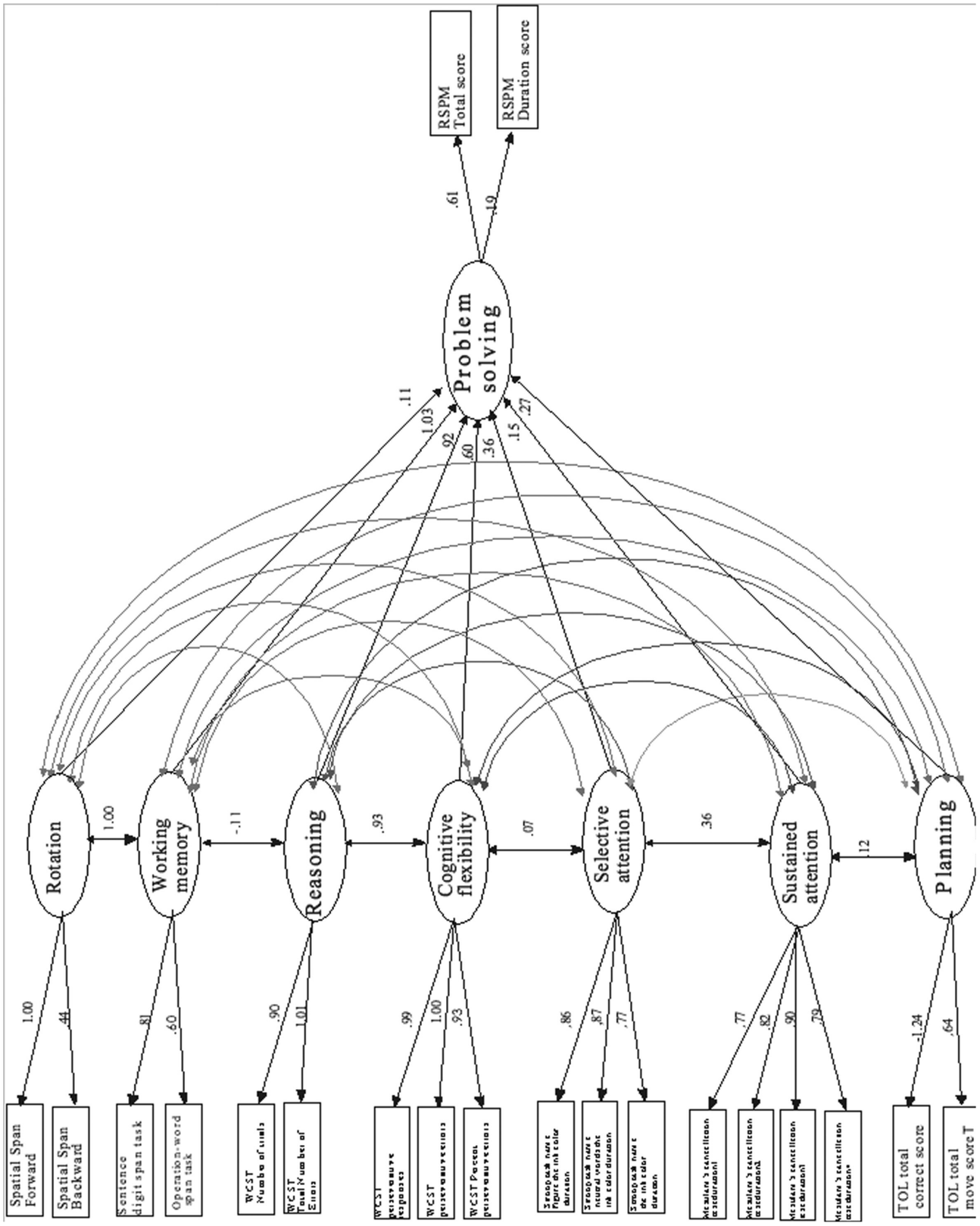
In this section, the relation of problem solving which is a cognitive process in itself with other cognitive processes was shown with 2D theoretical model in the sense of SEM analysis results obtained in the research. In the first dimension of model presented in Figure-2, three stages which take place in the mind directed to problem solving process; in the second dimension the relation of various cognitive processes with problem solving was shown. Both dimensions were formed depending on the findings obtained in the study.

The first dimension in the model depends on data obtained from insight technique from verbal protocole and results of content analysis carried out by the researcher. This dimension shows problem solving stages which take place in mind in problem solving process. According to the results of data obtained, this process takes places in three stages. (1) Determination of the characteristics of problem. At this first stage carried out for problem solving process, problem solvers examine the shapes that form the problem as a whole and try to understand the parts of whole. In this stage characteristic of the problem is analyzed conceptionally. An open-ended answer given by a participant to the qeustion of 'How did you solve the problem?' is: "First of all I examined the parts as a whole. While doing this, I tried to examine the shapes from left to right and from top to bottom." At this stage, characteristic of the problem is subjected to content analysis. (2) Determining a rule and making relation. In the second stage, the rules which form the problem are determined in order to

Table 2. Correlation coefficients between the latent variables in SEM

Rotation-Reasoning	.00
Rotation – Cognitive Flexibility	-.01
Rotation –Selective attention	-.27
Rotation – Sustained Attention	-.23
Rotation - Planning	-.12
Working memory- Cognitive Flexibility	-.04
Working memory - Selective attention	-.66
Working memory - Sustained Attention	-.25
Working memory - Planning	-.32
Reasoning - Selective attention	.08
Reasoning - Sustained Attention	-.02
Reasoning - Planning	-.05
Cognitive Flexibility - Sustained Attention	-.08
Cognitive Flexibility - Planning	-.12
Selective attention - Planning	.12

Figure 1. Structural equation model findings showing the relation between neuropsychological tests of study



solve the problem, similarities and differences are tried to be found by examining the problem in the basis of line ans column. A content analysis is done about making relationship between rules which form the problem. An open-ended answer of a participant: "Then I examined carefully. I examined from top to bottom, left to right, to the beginning and to the end and tried to make a relation between them." Another participant: "I tried to find the answer by examining similarities and differences". At this stage content analysis is carried out about the characteristics of problem. (3) Making decision and choice forms the last stage. At this stage, the choice is made by representing the right answer in mind and deciding on the choice which is compatible with mental representation. It is thought that a content analysis is done at this stage as well. The participant says: "I tried to find out which shape should be placed in the gap. After imagining the expected shape I serached the options and tried to find the answer, I mean the shape I have imagined among options". These stages occur as a result of inductive inference. Problem solver is thought to be doing bottom-up analysis in order to attain solution target. Stages of problem solving take place with bottom-up serial operation.

In the second stage of the model, the relationship between problem solving and various cognitive processes are shown. This stage was formed according to SEM analysis results applied on data obtained from neuropsychological tests in the study. According to this, cognitive processes such as reasoning, abstract thinking, mental flexibility, planning, destructive effect, mental rotation operate during problem solving process which is high-level cognitive process. During all these processes, working memory is used as an operation field. Reasoning, abstract thinking is done, a planning and strategy are formed for the target situation to be attained in problem solving process. In each stage of the problem, problem solver determines, relates the problem rules and compares them with solution option; makes reasoning, abstract thinking and concept learning in the process of decision making.

Change of wrong rule and relation system is done by mental flexibility cognitive process. In order to achieve target of problem solution, problem solver makes a strategy and plan. Excluding worng rules and relation system in solution-oriented thinking process means opposing to destructive effects. Transformation of shapes during observation the shapes of problem (in RSPM) in the sense of line and column is duration of mental rotation. During mental activities, working memory is used as coding, operation and storage area and takes place in the active management and direction as a cognitive process. In each stage such as identification of problem, determination of rules and achieving the target solution focused attention is required; in the process from the situation of problem to situation of target solution continuous attention is required. There is a parallel operation for all the cognitive processes related with problem solving process.

Not showing personal differences is thought to result from not showing mental flexibility for the solution of problem, in other words not resisting distractors under perseveration or destructive effect. Moreover it is thought that these individuals would not able to do correct reasoning and abstract thinking in finding correct rules for problem and accordingly skill of chanign the wrong rule and applying the new rule, in other words the skill of mental flexibility would be low. Moreover it is thought that these individuals would have inability in focudsing and sustaining the attention and managing working memory dynamically.

Compliance of Model to Literature

Problem solving stages which were formed depending on findings of the research were found to be compatible with studies carried out in literature. According to Ellis and Hunt (1997), problem solving process is composed of three stages. These are recognition of problem, forming alternative hypothesis for the solution and choosing one of them, valuating the solution and testing. In the study problem solving process is composed of three similar stages. Newell and Simon (1972) asserted that thinking processes related with problem solving process is composed of two stages, these are; recongition of process and search of process. It is thought that problem solving process obtained from the research is compatiblae with the results of Newell and Simon (1972), perceptual and content analyses carried out the mentioned process is a cognitive activity for the recognition and search of process.

In the literature it was expressed that in studies carried out with RPM, RPM is frequently used as a factor of fluid intelligence/analytical thinking/general skill; put forward the relationship between cognitive processes such as working memory, attention, reasoning, planning, operation speed etc (Ackerman et al. 2002, Colom et al. 2005, Colom et al. 2003, Engle et al. 1999, Kane et al. 2004, Kafadar 2004a, 2004b, 2010, 2011, Necka 1996, Roberts et al. 1991, Roberts et al, 1988, Stankov et al. 1994, Unsworth and Engle 2005, Verguts and De Boeck 2002, Wang and Chiew 2010). In this study, there was a relationship between scores obtained from RSPM and other neuropsychological tests (Figure 1). This finsing is compatibale with other research results carried out in

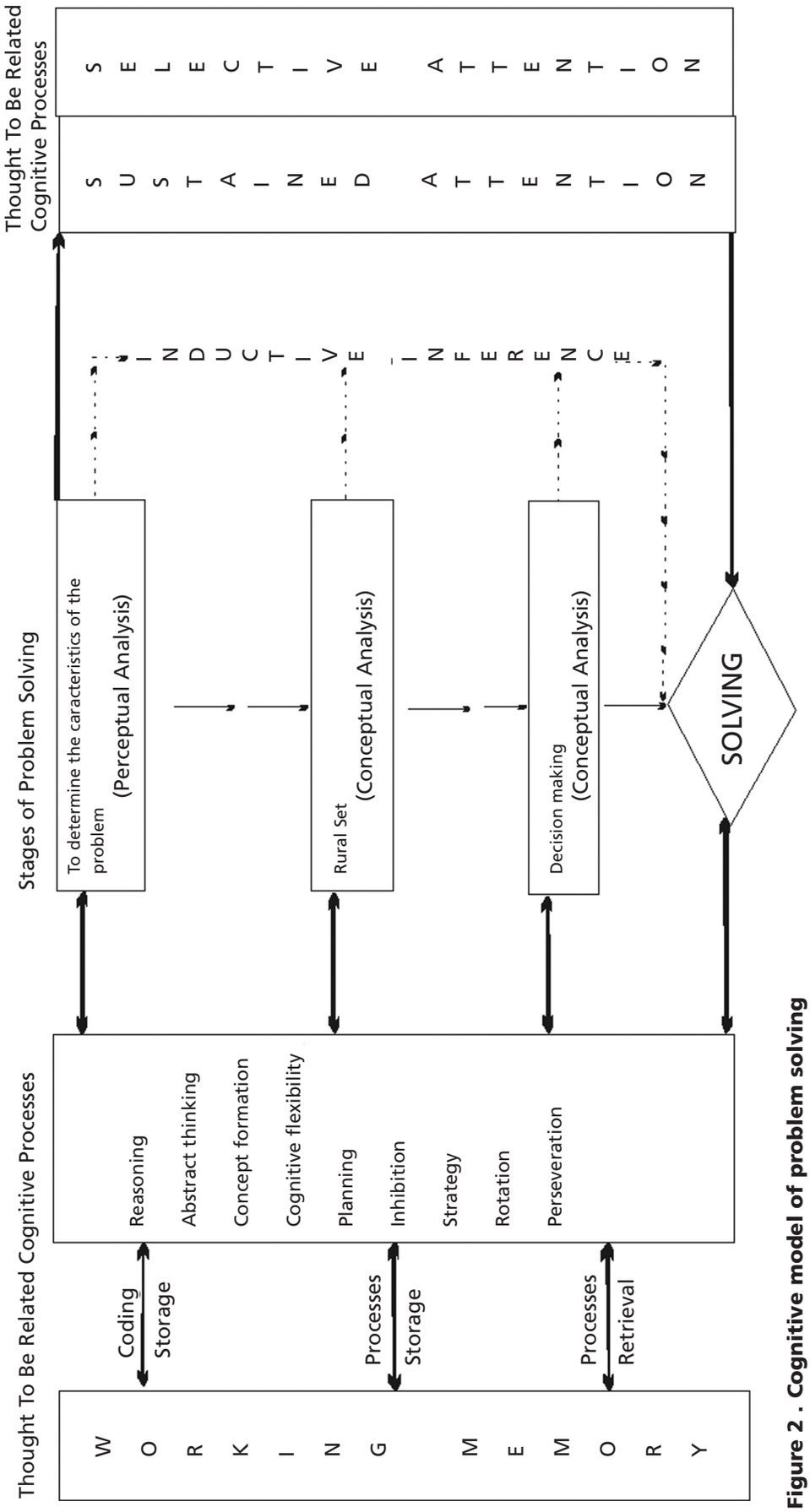


Figure 2 . Cognitive model of problem solving

the literature. However in the previous studies of literature, relationship between RPM and other cognitive processes were examined seprartely. In the current study RSPM which is one of RPM tests was regarded as a problem solving test and since it is thought to have relation with problem process cognitive processes were observed in a single study and its contribution to problem solving was tried to be determined. When the study is regarded in this sense it is thought to have important contribution to literature.

CONCLUSION

In the study it was aimed to examine the relation between RSPM, WCST which measure reasoning, abstract thinking, mental flexibility, KUG which measure the capacity of working memory, Stroop Test which measure focused attention, Cancelletion Test which measure continuous attention and Tower of London which measure planning and strategy making, GBU which measure mental rotation, prediction relationship among each other and model description.

With this research it was aimed to show how some specific mental processes operate in a healthy person and their relationship with each other. The difference of study is that it examines so many tests at once and uses a statistical technique that would put forward descriptive model relations between each other. Putting forward the relationship between problem soving and other mental processes is important in the sense of bringing different perspective for the recongition of cognitive processes of a healthy person. Moreover it is thought that practical benefits would be obtained from the findings about problem solving process which is a common point of different fields such as education, law, sport, industry. Especially in the education field, forming programs which aims the improvement of problem solving skills and which cognitive processes should be developed for the children in these programs can form the practical sides of the research. Findings would provide providence about what other mental processes would deteriorate on neurological and psychiatric patients whose specific mental processes have destroyed. This information would be instructive in forming rehabilitation programs for deteriorating mental processes. According to research findings, there is a predictive relation between problem solving and working memory, reasoning, abstract thinking, mental flexibility, operative functions, planning, strategy making and attention types. Common point of these mental processes is to perceive the relationship between elements in complex conditions, identify and store these complex relations, make operations and planning among them and attain the correct result.

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